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Glass Production in Colonial Mexico: Technology Transfer, Adoption, and Adaptation



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# Glass Production in Colonial Mexico:

# Technology Transfer, Adoption, and Adaptation

A thesis submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Archaeology

by

Karime Castillo Cárdenas

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ABSTRACT OF THE DISSERTATION

Glass Production in Colonial Mexico:

Technology Transfer, Adoption, and Adaptation

by

Karime Castillo Cárdenas

Doctor of Philosophy in Archaeology

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Professor Ioanna Kakoulli, Chair

Through a multidisciplinary and cross-disciplinary approach at the interface of archaeology, ethnography, history, and materials science, this research investigates how glass technology was transferred in the sixteenth century from Europe to the Americas, where artificial glass had never been made before. With a focus on colonial Mexico the research explores how the technology was adapted to the resources available, and how it was used in the negotiation of multiethnic social relationships in colonial Mexico. Guided by thorough historical research, and informed by ethnographic observations in traditional glassblowing workshops in Jalisco and Puebla, the chemical composition of archaeological glass from Mexico City and Puebla, the two main glass production centers in the viceroyalty of New Spain was investigated. Archaeological glass from Catalonia, Spain was also analyzed for comparanda. This research shows that colonial glassmakers trying to establish their craft in the New World faced several challenges ranging

from raw materials availability and quality, restrictions on fuel procurement, and scarcity of specialized labor. The results of the analyses expose some of the ways in which colonial glassmakers responded to these challenges by using local raw materials following the tradition prevalent in the Iberian Peninsula at the time, which relied on halophytic plant ash as the fluxing agent. The analysis further showed how artisans adapted when the local halophytic plants failed to produce the desired results; they incorporated an additional fluxing agent, the local evaporite *tequesquite*, which was not used in Spain. Furthermore, the research shows glassmakers relying on indigenous traditional ecological knowledge and labor to obtain both types of alkali, which had been exploited by them since prehispanic times. Without the reliance on indigenous communities and their knowledge, the successful transfer and further development of glass technology would not have been possible.

The dissertation of Karime Castillo Cárdenas is approved.

Christian Fischer

Richard Lesure

John Papadopoulos

Kevin Terraciano

Ioanna Kakoulli, Committee Chair

University of California, Los Angeles

2020

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## ACKNOWLEDGEMENTS

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2002 Archaeological Project "El Bajío", Sonora

# 1. INTRODUCTION

Glass is a fascinating material. Although it is hard to the touch, the way its atoms are arranged is more akin to that found in a liquid (Freestone 1991:38). It can be coiled, cast, molded, and blown. It can be made into a wide variety of colors, transparent and opaque. Its impermeability to oil and liquids, minimum of chemical reactivity, and ease to clean and reuse have made glass the ideal material to make containers and bottles. Its transparency allowed the owner to inspect the contents of the vessel, which make it suitable for the storage, preservation, display, and merchandising of all sorts of commodities (Grose 1984:31). It has enabled the development of science and allowed people with vision problems to see. And although the technology was not developed in the Americas, it has been around for more than 5000 years (Tait 2004:8).

Glass was introduced into Mexico as a fully developed technology in the Early Colonial period (1521-1650 (Charlton 1968:99)), but until now, little was known about how this technology was transferred from Europe to the New World. Exploring this process, and the ways in which colonial glassmakers adapted the technology to the local resources, taking into account all the people involved in the process as well as the particular circumstances of the colonial context in which it took place are the main objectives of this research. Chapter 2 introduces glass in terms of its scientific definition, structure, and properties, followed by a brief history of the development of glass technology worldwide. Glass as an archaeological material comes with particular challenges which, in Mexico, combined with its recent temporality have deterred people from embarking in its study. However the material holds enormous potential for the exploration of a variety of subjects, ranging from the history of science and technology in

Mexico to very specialized topics such as artificial lighting. These and other opportunities available through the study of archaeological glass are also discussed. An overview of the scholarship on glass in Mexico helps to understand the state of the art and the different approaches that have been used to investigate the history of glass in Mexico, identifying current limitations and misconceptions and pointing out how this work helps to address these issues.

The third chapter places the research within the field of historical archaeology, a field that has experienced tremendous growth in Mexico in the past ten years, broadening its scope to a global perspective and venturing into a wide variety of subjects. The chapter also presents the theoretical perspectives that guided the research. Archaeology of colonialism and postcolonial theory are discussed placing particular emphasis on how these approaches apply to the cases of Latin America and Mexico. The anthropology of technology is also reviewed with a particular emphasis on the studies that have been conducted in Mexico and presenting diverse methods that have been used to investigate technology including: ethnoarchaeology, experimental archaeology, and archaeological sciences. A discussion follows that emphasizes the value of bridging the divide between science and humanistic and social sciences approaches to the study of the past.

Chapter 4 explains the multidisciplinary approach applied in this study, which combines archaeology, ethnoarchaeology, historical research, and materials science principles and methods to look at glass technology at multiple scales, from the local to the global. This chapter presents the methods used to propose a typology for archaeological glass, as well as the scientific method used to analyze the chemical composition of the glass and the potential raw materials used. The analytical techniques to study potential raw materials included fiber optics reflectance spectroscopy (FORS), X-ray diffraction (XRD), and SEM-EDS. The multi-analytical methodology applied to characterize the archaeological glass collection combined optical and digital microscopy (OM and DM), scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy (EDS), electron probe microanalysis (EPMA), and laser ablation inductively coupled plasma mass spectrometry (LA-ICP/MS).

The fifth chapter sets the stage to explore the introduction of glass, and the technology to make it, into the Americas by looking at the use of a widely used natural glass known as obsidian in prehispanic Mesoamerica, as well as other materials of glassy appearance such as rock crystal, alabaster or *tecali* stone, as well as gemstones like amethyst, certain types of jade and opal, emerald, and amber. The chapter explores how these materials were perceived and used in Mesoamerica emphasizing the characteristics they share with artificial glass that were sought after and valued in Mesoamerica, such as resplendence, shimmer, translucency, smoothness, sharpness, and iridescence. It presents an overview of the various uses, symbolisms, and associations glass-like materials had in Mesoamerican cultures with a focus on the Postclassic period, the era preceding the arrival of the Europeans to the New World.

The historical records that guided this research are presented on Chapter 6, which explores the arrival, establishment, and development of glass and glass technology in New Spain. The chapter focuses on the two main glass production centers of the viceroyalty: Mexico City and Puebla, and discusses the organization of the craft as well as the people involved in the industry, which included not only Spanish glassmakers but also indigenous communities, people of mixed ethnicity, women, and slaves. This chapter highlights the fact that glass artisans heavily relied on the traditional ecological knowledge of indigenous communities in terms of raw material supply, the active involvement of enslaved people in the production process, and the entrepreneurship of certain women in the industry.

Chapter 7 presents the archaeological material, which includes: a selection of glass from five sites in the historical center of Mexico City; a collection of glass recovered from five sites in the historical center of Puebla; and a comparative collection of archaeological glass from two sites in Catalonia. The chapter presents two typologies: one for Mexican archaeological glass and one for Catalan glass. They were built in a traditional way with the intention to provide details and information to categorize a glass collection when the analysis of the chemical composition of the glass is not possible. Given that the material from Mexico included production waste, the chapter incorporates ethnoarchaeological observations made in tradition blown-glass workshops in Jalisco and Puebla into the interpretation of the waste products as well as on certain manufacturing techniques.

Chapter 8 discusses raw material selection for glassmaking in the context of colonial Mexico. After presenting an overview of the raw materials used in glass production, the chapter explores possible sources guided by historical records. In addition, the chapter presents the analysis of two potential fluxing agents used by colonial glassmakers: ashes of salt-tolerant plants, following the glassmaking tradition prevalent in the Iberian Peninsula; and the local evaporite *tequesquite*, both of which were exploited by indigenous communities in prehispanic Mesoamerica. The results are then used to both interrogate the historical sources and to interpret the results of the analyses of the archaeological glass collections.

The ninth chapter presents the results of the analyses of the chemical composition of archaeological glass from Mexico and Catalonia with a focus on the identification of raw materials, in particular sands, sources of alkali, colorants, decolorizers, and opacifiers. The purpose of these analyses was to assess if the technology used by colonial glassmakers followed the Iberian tradition or departed from it, and to investigate its adaptation to the local resources.

Chapter 10 explores glass from a local and global perspective. At the local level, it discusses how glass was valued and used by people in colonial Mexico to negotiate social relations. At the global level it discusses the global influences facilitated by transoceanic trade that shaped consumer demand and the products made, and it explores the places that colonial Mexican glass reached beyond the viceroyalty of New Spain.

The story of glass technology in Mexico cannot be told from a single perspective. Multiple and complementary lines of evidence are needed in order to explore this multi-faceted subject. What becomes clear is that Spanish glassmakers alone would have not been successful in the establishment, adaptation, and development of the craft without the active participation and traditional ecological knowledge of indigenous communities and enslaved people. The research also shows the impact of early globalization in the lives, aspirations, and needs of different communities interacting together in a colonial setting. Everything changed after 1492. The study of glass technology brings to the fore the interactions between people of very different backgrounds in the production of a material, simultaneously old and new, that soon became part of the large repertoire of adaptations, innovations, and hybridizations that resulted from this cultural encounter.

## 2. GLASS: DEFINITION, HISTORICAL DEVELOPMENT, AND STUDY

### 2.1. Glass: Definition, Structure, Properties, and Manufacture

Most glasses are made of minerals with a high valence state[1] (*i.e.*, silicate, phosphate, boron) that are heated until they melt. There are countless different chemical compositions that can be made into glasses and therefore, it is not the chemical composition what defines glass, but its physical structure and atomic arrangement (Brill 1962:127; Tooley 1974:3; Zachariasen 1932). Glass is often referred to as a "super-cooled liquid," meaning a molten material that cooled down rapidly and did not crystallize. As glass cools down the viscosity increases which significantly hinders the mobility of the atoms in the melt to the point that they cannot reorder themselves. The material is then turned rigid, solidifying over a range of temperatures and remaining amorphous, that is, with a relatively random internal structure that resembles that of a liquid. Glass can therefore, be defined as an inorganic amorphous solid that unlike crystalline[2] materials, has no regularity in the arrangement of its molecular constituents (Fernández-Navarro and Villegas 2013; Henderson 2000:24; 2013:1; Pollard and Heron 2008:145). From a thermodynamic point of view, glasses can be considered as frozen in an unstable state. A system is at its most stable state, when the energy of the system is the least. Most solids reach this stable state when they crystallize. A super-cooled liquid however, has an internal energy that is higher than that of the corresponding crystalline phase with the same composition (Fernández-Navarro and Villegas 2013:2; Goffer 2007:113).

[1] A high valence state means that an atom has a surplus or deficit of electrons allowing it to bond easily with other atoms (Callister 2007: 21-22).

[2] In a crystalline material the atoms are located in a periodic array over relatively large atomic distances (Callister 2007: 39).

Characteristic to glasses is their conchoidal fracture resulting from their amorphous structure; the lack of long-range structural order in its molecules allows the shock waves to pass through the material unhindered, leaving a curved shell-like concentric pattern on the broken pieces (McLeish 1992:12). Materials that have an ordered crystalline lattice[3] such as quartz, the most common form of crystalline silica, are made of a three-dimensional structured network of repeated unit cells (the smallest units that have the full symmetry of the full crystal structure). In contrast, the molecular structure of glasses is irregular and far more disorganized. The bridges between the oxygen and silicon atoms can be broken and other elements such as sodium or calcium present in the glass are randomly distributed (Figure 1) (Henderson 2013:2-4). The disordered molecular structure of glass in some ways resembles that of a liquid, but the glassy state does not actually fit in any of the states of matter: solid, liquid, or gaseous (Brill 1962:127); for this reason some authors consider the vitreous state as an additional state of matter (Pollard and Heron 2008:145).

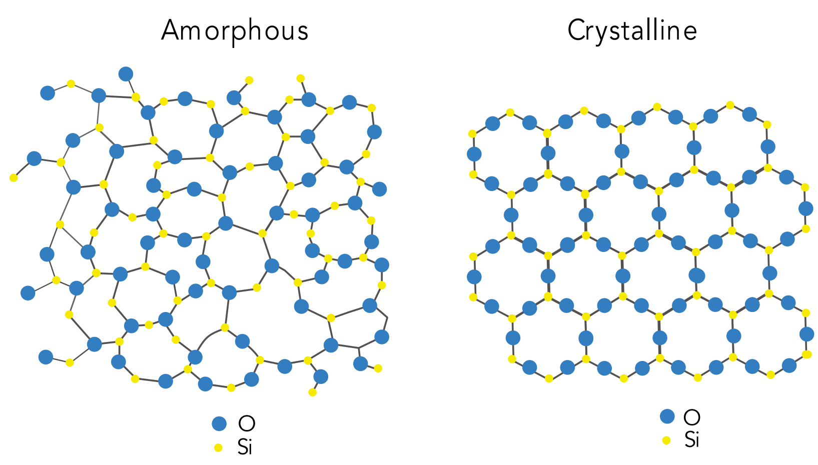



Figure 1. Comparison between the anamorphous molecular structure of glass (left) and the crystalline structure of quartz (right).

[3] The term lattice refers to a three-dimensional array of points representing atom positions in a molecular structure (Callister 2007: 40).

An important characteristic of glasses is their plastic-viscous behavior over a wide temperature range (Figure 2). Critical in this respect, is the transition temperature (*Tg*), which determines when the properties of glass change from those of a liquid to those of a solid and vice versa. As glass cools down and approaches the transition temperature its volume begins to decrease, its viscosity increases, and the rearrangement of its structure slows down. Around 1100ºC the viscosity of glass increases to the point that it can be gathered and at 1000ºC it becomes more malleable and is soft enough to be blown. Glass progressively stiffens as it cools down but it can be softened through reheating. As temperature rises, glass progressively softens going through various stages of malleability, allowing it to be reshaped and softened repeatedly to make an object. Once glass cools down, it hardens into an amorphous brittle material, with a smooth, glossy surface, retaining the shape achieved before it became rigid (Fernández-Navarro and Villegas 2013:11; Grose 1984:9; Henderson 2013:4-5; Paynter and Dungworth 2011a:3; Whitehouse 2012:10).

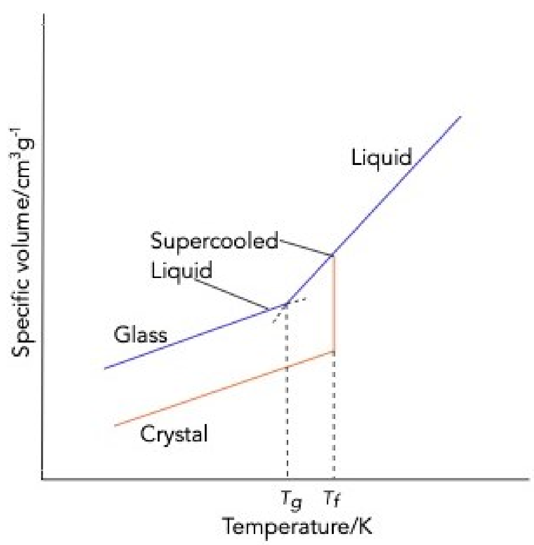



Figure 2. Variation in volume of glassy and crystal phases with the same composition according to temperature. *Tf* stands for melting temperature (modified from Fernández-Navarro and Villegas 2013:2; Fig. 1.1.1).

The optical behavior of glasses depends on their refractive index, optical dispersion, and absorbance. Most glasses are transparent to visible light because their strongly bonded electrons do not interact with light photons, however, the percentage of light that is transmitted (Figure 3a) or passes through a glass depends on its refractive index. When a beam of light reaches its surface, part of it is reflected (Figure 3b) and part of it passes through the material by changing its path (Figure 3c). The degree to which light is bent when crossing the air/glass interface is the refractive index. The higher the refractive index of a glass, the higher its reflectance and brightness, and the lower the percentage of transmitted light. Dispersed small particles within the glass can scatter light in many directions (Figure 3e) and this can contribute to having opaque glasses (Fernández-Navarro and Villegas 2013:17; Goffer 2007:82, 84-85). Dispersion refers to the property of white light to be separated into individual colors as it passes through the glass, but if a glass contains elements that selectively absorb radiation of a specific wavelength (Figure 3d), such as transition metals, it will show a color.

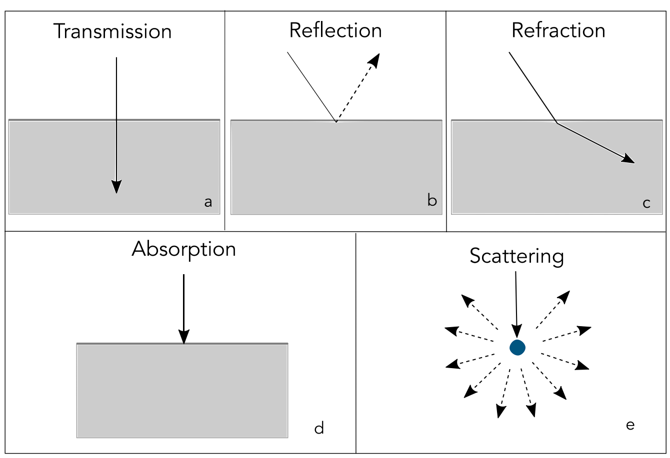



Figure 3. Optical behavior of glass: a) transmission; b) reflection; c) refraction; d) absorption; e) scattering.

In addition to its transparency, glass is also a durable, highly inert, and unreactive material impermeable to liquids; it is lightweight and can be easily cleaned and reused; when broken, it can be re-melted and recycled into a new object. All of these characteristics have made it a tremendously useful and versatile material throughout history (Fernández-Navarro and Villegas 2013:3; Grose 1984:9; Pollard and Heron 2008:144).

Glass is usually made of three basic components: 1) a network former which can create a cross-linked network of chemical bonds to readily form a glass, like silica ($SiO_2$) found in sand, quartz, or flint; 2) a network modifier known as flux which is added to lower the melting temperature of silica, such as soda (NaOH), carbonates of soda, or potash (KOH) obtained from plant ashes, mineral salts, or lead oxide; and 3) a network stabilizer to reduce the solubility of the glass, mainly lime/calcium carbonate/oxide ($CaCO_3$/CaO). By varying the proportions of these main components, the melting and working properties of glass can be modified (Henderson 2013:5). Other ingredients can be deliberately added to the batch[4] in order to add/remove color or to make the glass opaque. Most common such additives include: copper (Cu), or cobalt (Co) as colorants, antimony (Sb) and manganese (Mn) as decolorizers, and red cuprous oxide or cuprite (CuO) and tin oxide (SnO) as opacifiers. These main raw materials for glassmaking will be discussed in more detailed in Chapter 8.

It is important to make an important distinction between two terms related to glass production: glassmaking and glassworking. Glassmaking refers to the process of heating and reacting together the raw materials to make glass and is also known as primary production. Glassworking or secondary production refers to the shaping of glass into objects (Paynter and Dungworth 2011a:4; Whitehouse 2012:10-11). These processes can take place at the same site, or at separate primary and secondary workshops, as was practiced in antiquity in the Old World (Freestone 2005:2). Some authors consider an additional stage of tertiary production, which

[4] The term batch refers to a mix of raw materials which when melted produce glass (Paynter and Dungworth 2011: 31).

refers to modifications done to an annealed[5] glass object using cold-working techniques to decorate it including painting, gilding, engraving, cutting, and etching (Tait 2004; Whitehouse 2012:10-13).

Glass is the first human-made translucent solid, but it can also be found in nature. The best know example of natural glass is obsidian, which forms when magma flowing out from a volcano cools down rapidly. Glassy materials can also be formed from the impact of asteroids or lighting on sand, forming tektites and fulgurites respectively; they can be a byproduct of other pyro-technologies such as metallurgical processes, in which case they are known as glassy slags; and they can result from high-temperature events such as fires (Henderson 2013:1, 6; Paynter and Dungworth 2011a:3).

## 2.2. A Brief History of Glass Technology

Of the three main pyrotechnologies since ancient times, glassmaking was the last to appear, following pottery and metalworking. Other vitreous material preceded artificial glass, including glazed steatite, faience, and frits (like the Egyptian blue pigment). The earliest evidence of vitreous materials in the form of beads, rings, small figurines, and bowls emerged in the Near East and Egypt and date back to the fourth millennium BCE (Tite and Bimson 1989:87). Glazed steatite (Figure 4a) was developed before faience sometime during the fifth millennium BCE in Egypt, the Near East, and the Indus Valley. Steatite is a soft stone composed mainly of talc which was carved into small objects that were then covered with an alkaline silica-based glaze mixture or immersed in an alkaline copper-rich glazing mixture before being fired. The glaze formed when the alkali and the copper present in the glazing mixture interacted with

[5] Annealing is the process of cooling down glass gradually in a relatively controlled manner (Phillips 1981: 286; Whitehouse 2012: 13).

the steatite body (Tite and Bimson 1989:98; Tite and Shortland 2008:17). Faience (Figure 4b) appeared in the Near East towards the end of the fifth millennium BCE and it progressively took over from glazed steatite. Faience consists of a ground quartz body that is bonded together by glassy phases and is coated with a glaze (Tite and Shortland 2008:17).

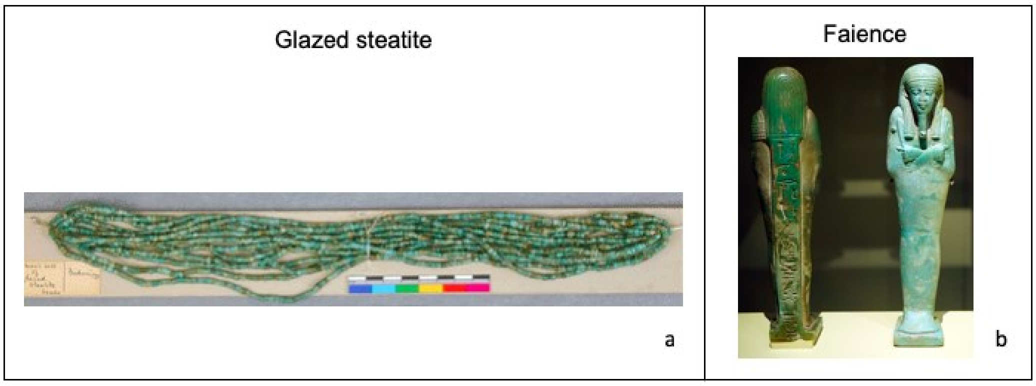



Figure 4. Examples of early vitreous materials: a) Glazed steatite beads from Badari Tomb 5735, *ca*. 4400-4000 BCE (Quirke et al. 2000); b) Two shabits of Psamtik-men, Museo Arqueológico Nacional, Madrid, 664-332 BCE (photo: Karime Castillo).

It is still unclear when glass as an artificial material was made for the first time, but the earliest examples come from Mesopotamia, which occupied the area that today is northern Syria and Iraq. Among the earliest evidence of glassmaking is a lump of blue glass found in Eridu, Iraq, dated to the Bronze Age, *c*. 2300 BCE (Garner 1956; Henderson 2013:8). Early glass was made in small quantities from silica and plant ash fused together in a crucible and it was used to make beads, which represent some of the first glass artifacts (Henderson 2013:8). Some of the earliest examples have been found in Tell Judeideh, Syria: a blue and a green bead dated to the earlier third millennium BCE (Moorey 1994:190). Other early glass artifacts include small pendants and amulets made by pouring or pressing glass into open molds (Whitehouse 2012:11). Glass of different colors and degrees of opacity such as turquoise, cobalt blue, opaque yellow, and opaque red began to be made around the mid-fifteenth century BCE and it is possible that deliberate attempts to modify the color and opacity of glass were done in order to produce imitations of precious stones (Henderson 2013:10). Around this time, the first glass vessels appeared in Mesopotamia. Closed vessels of small dimensions were made using a technique known as core-forming in which the glass is shaped around a removable core that has the desired final shape (Figure 5a and 5b). Open vessels were made by fusing together slices of glass rods arranged in a mold as a mosaic in colorful patterns (Figure 5c and 5d). In Egypt, glass objects including beads and amulets have been found as grave goods in burials dating to *c*. 1550 BCE, and core-formed and mosaic vessels some decades later (Saldern 1980:15-16; Tait 2004:22-23; Whitehouse 2012:17-18). These techniques extended throughout the Mediterranean and were used by the Myceneans in Greece and the Phoenicians in the area of modern Lebanon; the later also made cast bowls using hemispherical molds with complex decorative features. Knowledge of glassmaking also spread to the emerging Iron Age cultures along the Adriatic coastline, Italy, and southern Austria. Although glass technology was spreading, the scale of production remained small so glass was a rare and costly commodity (Grose 1984:15, 17-18; Tait 2004:41; Whitehouse 2012:23-26).

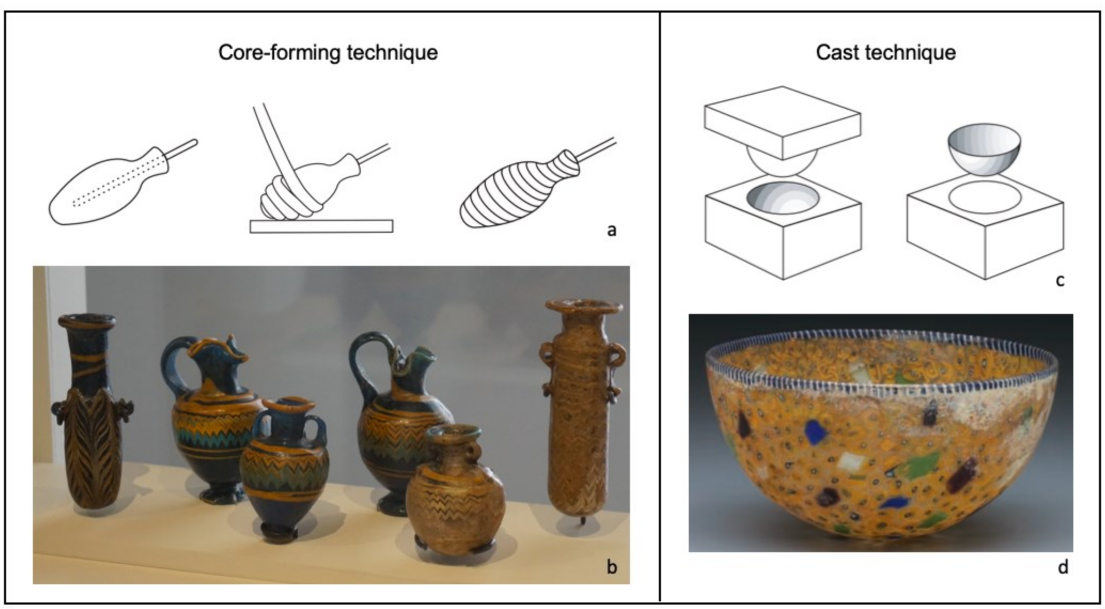



Figure 5. Ancient vessel-forming techniques: a) core-forming technique (Grossman 2003:7, fig. 3); b) core-formed unguentaria, Museo Arqueológico Nacional, Madrid, 6th-5th century BCE (photo: Karime

Castillo); c) cast technique (modified from Grossman 2003:8, fig. 6a); d) cast mosaic bowl, Eastern Mediterranean, late 2nd-1st century (Grossman 2003:8, fig. 7).

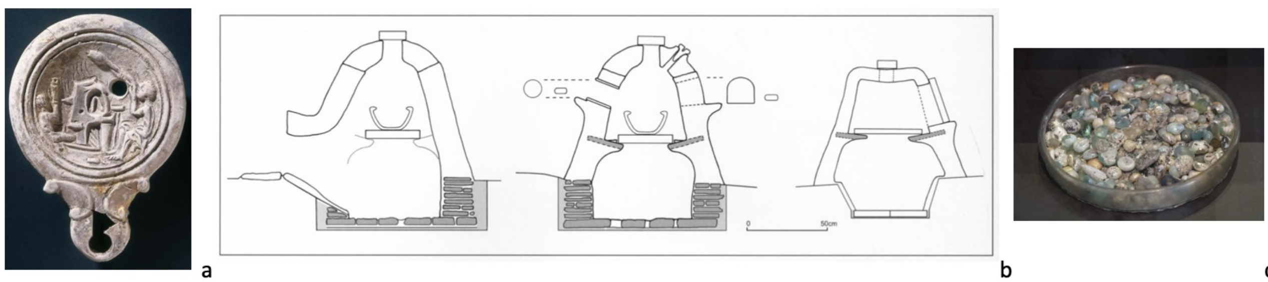
During the Hellenistic period in Greece (323–31 BCE), glass casting continued and was used to make objects that copied the shape of contemporary pottery, silver, or bronze vessels. The technique of mosaic glass was further developed in Egypt during this period by making intricate patterns with rods of glass of different colors assembled together in a bundle that was heated to fuse the rods together into a single cane. This cane was then stretched, making the cross-section smaller but preserving every detail in the design, and cut into slices, known as *millefiori*, which were used as inlays or assembled and fused together into a colorful object. Another technique developed at this time was the gold-glass or gold "sandwich" glass (Figure 6), which consisted on placing gold foil in between two layers of glass (Grose 1984:20; Phillips 1981:28; Saldern 1980:20; Tait 2004:49, 52; Whitehouse 2012:27-28). At this point, under the Qin Dynasty (221-206 BCE) small glass objects were being made in China, although glass beads, probably imported from the Near East, appear since the Warring States period (475-221 BCE) (Zerwick 1990:35).

Figure 6. Hellenistic gold-glass skyphos, Metropolitan Museum of Art, Eastern Mediterranean, 2nd century BCE (Metropolitan Museum of Art online catalogue).[6]

[6]https://www.metmuseum.org/art/collection/search/251409?searchField=All&sortBy=Relevance&ft=hellenistic+gold+sandwich+glass&offset=0&rpp=20&pos=5.

It should also be noted that since *c*. 800 BCE, the preferred source of alkali was no longer plant ash but natron, an evaporite mineral that accumulates on the dry beds of saltwater lakes composed of the sodium sesquicarbonate trona (Henderson 2000:26). Natron glass was predominantly made until *c.* 800 CE in the West and the Middle East. Natron had the advantage of being a relatively pure source of alkali compared to plant ash, and resulted in a glass with a somewhat more predictable behavior when worked (Henderson 2013:51).

During Roman times, glass technology bloomed and diversified in extraordinary ways. In the early to mid-first century BCE, glass artisans discovered that the material could be blown. This discovery revolutionized the industry, resulting in a major increase in the variability of shapes and sizes that could be made, as well as, in the speed and scale of production. Glass became available to a much larger audience than ever before, as utilitarian objects for everyday use began to be made. While fine glassware such as cameo glass and cage cups continued to be luxury items and accessible only to the elite, the material itself was no longer an extravagance. In Roman times, glass manufacture transformed from a relatively minor craft to an Empire-wide industry, with glass artisans setting up workshops in the western and northern provinces, including Spain, Gaul, Asia Minor, and before the end of the first century, Britain and Germany (Douglas and Frank 1972:4; Grose 1984:11, 24; 1991:1; Tait 2004:78; Whitehouse 1988:5-6). The origin of glass-blowing seems to have taken place somewhere close to the east coast of the Mediterranean, in present-day Lebanon or Israel. The earliest examples of blown glass vessels were made out of a hollow tube of glass pinched shut at one end and blown through the other to form the vessel (Grose 1984:26; Tait 2004:62; Whitehouse 2012:31). However, glass-blowing was perfected at the heart of the Roman Empire, today Italy, thanks to the implementation of technological innovations including: furnaces that allowed for higher temperatures to be reached (Figure 7a and 7b); the development of the iron blowpipe (Figure 7a); the invention of the pontil technique that allowed the rim of the vessel to be worked; the use of molten glass contained in crucibles (Figure 7b); and the realization that glass could be re-melted and recycled (Figure 7c) (Stern 1999:446).



a b c

Figure 7. Roman innovations: a) lamp depicting a furnace and glassblowers using a blowpipe, Spodnje Škofije, Slovenia, $2^{nd}$ century CE (Lazar 2006:230, Fig.232); b) reconstruction of a Roman glass furnace with crucible by Taylor and Hill (2008:252, Fig. 252); c) Glass droplets for recycling, $1^{st}$-$2^{nd}$ century, Museo Arqueológico Nacional, Madrid (photo: Karime Castillo).

Another development that took place in the Roman Empire was the making of windowpanes (Figure 8a), mostly cast but also cylinder-blown.[7] Colored glass sheets were also used to make tesserae for mosaic panels. Glass began to appear prominently in architecture, examples of which can be found in Roman villas, and the Roman baths of Caracalla, Herculaneum, and Pompeii (Figure 8b) to mention a few (Allen 2002:102, 106-109; Grose 1984:31; Price 2005:184).

[7] Cylinder-blown glass, also known as broad glass, was made by blowing a gather of glass, elongating it into a cylinder, removing the ends, slitting the glass tube along its length and opening it up to make a flat pane (Paynter and Dungwhorth 2011: 31; Roenke 1987: 6).


Figure 8. Roman architectural glass: a) window pane, *ca*. 3rd-4th century CE, Museu de Mataró; c) Travelling Musicians, wall mosaic from Villa de Cicero, Pompeii, 1st century BC, Museo Archeologico Nazionale di Napoli (photos: Karime Castillo).

The rise of glassblowing came with new decorative techniques. Soon after the discovery of glassblowing came the realization that glass could be blown into decorated molds, leading to an assortment of quickly-made tableware (Figure 9a), containers for cosmetics, square and prismatic bottles (Figure 9b), as well as mold-blown objects of very high quality depicting scenes from Greco-Roman mythology. Applied decoration in the form of trails that spiraled around a vessel, plantlike or snakelike trails (Figure 9c), and patterns of stripes and loops that were sometimes flushed into the object's walls through marvering[8] became common. Cold decorative techniques such as cutting and engraving to form patterns, figures, and scenes also became widely used. Other forms of decoration used by Roman glass artisans included enamel, cold-painting, and gilding (Saldern 1980:22-25; Whitehouse 1988:6-7; 2012:32, 39).

[8] To marver is to roll or press a glass blob or object against a flat surface or marver to shape it (Paynter and Dungworth 2011: 31).


Figure 9. Examples of Roman glass: a) mold-blown bowl, *ca.*1st century CE, Museo Lázaro Galdiano, Madrid; b) mold-blown bottles, 1st-2nd century, Museo Arqueológico Nacional, Madrid; c) bottle decorated with snakelike trails, *ca*. 2nd century, Museo Arqueológico de Sevilla (photos: Karime Castillo).

Around the mid-first century CE, colorless glass achieved primarily through the addition of antimony, became trendy. Decolorized glass had the novelty of high transparency and it also allowed glass artisans to exploit the optical properties of glass by faceting and engraving the surfaces of glass vessels. Cast and intentionally colored glass declined in popularity but neither was completely abandoned (Grose 1984:28; Tait 2004:76; Whitehouse 1988:6). One of the major Roman innovations in terms of colored glass, was the dichroic glass, which showed the glass in a different color depending on whether light was reflected from its surface (direct light; Figure 10a), appearing jade green, or when it shined through the glass (transmitted light; Figure 10b), turning red. This effect was achieved through the dispersion of gold and silver nanoparticles in the glass; the most notable example of this type of glass is the Lycurgus cup on display at the British Museum (Freestone et al. 2007; Grose 1984:13).

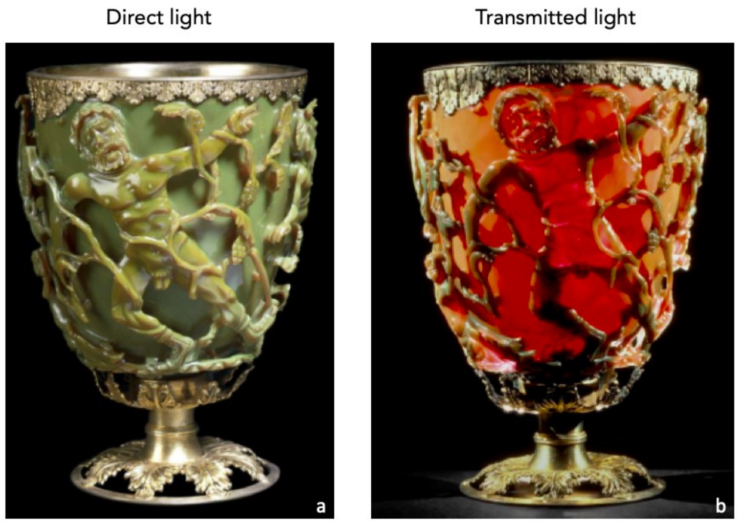


Figure 10. Lycurgus cup, 4th century CE; British Museum: a) under direct light; b) under transmitted light (The Trustees of the British Museum).[9]

After the fall of the Roman Empire and despite the upheavals and political restructuration that followed as Europe entered the Middle Ages, remnants of the Roman glass industry survived, allowing for the glass industry to develop further. In some parts of Italy, Germany, and Switzerland glassmakers strived to produce colorless glass by selecting the purest raw materials possible and adding manganese to the batch. The production of domestic glass, particularly for serving and consuming beverages, was strong in the Middle Ages, but new types of vessels for alchemy and medicine began to appear. Another Medieval innovation is the invention of spectacles in Italy (Whitehouse 2012:43-45).

Most of the late Medieval glass produced in central and northern Europe was made in small workshops located in the forests where fuel from resinous trees and potash from beech wood, bracken, and other woodland plants were readily available. Drinking vessels and bottles of "forest glass"[10] represent most of the production (Figure 11). This potash glass became characteristic of central Europe, whereas soda glass continued to be made in coastal regions. The

[9] https://www.britishmuseum.org/collection/object/H_1958-1202-1.
[10] Forest glass is known as *verre de fougère* in France and *waldglas* in Germany and Bohemia (Phillips 1981:47).

Medieval era also saw the rise of window glass, including cylinder glass, crown glass,[11] and stained-glass windows. The latter made their appearance in abbey windows of the Carolingian period and reached their zenith in the cathedrals of the Gothic period (Douglas and Frank 1972:6; Phillips 1981:47-48; Vose 1984:45, 48; Whitehouse 2012:47).

Figure 11. Forest glass beaker with prunts, 13th-14th century, Germany, Corning Museum of Glass (Whitehouse et al. 2010:127).

Glass production continued also into the Byzantine and later the Islamic world where gilded and enameled luxury glass and *tesserae* for the decoration of churches were made, acquiring an aesthetic of its own (Vose 1984:39, 58-59; Whitehouse 2012:48). Islamic glass artisans became masters of wheel-cut and relief-cut glass and they also developed the glass painting technique of metallic stain, which was achieved by painting the surface with a mixture of sulfur and powdered copper or silver oxide suspended in an acidic medium and then fritting it so the metal got absorbed into the glass. This technique, also known as luster, seems to have discovered in Egypt or Syria in the eighth century. Later, gilded and enameled glass showcasing rhythmic decorative patterns, figurative or geometric designs, and calligraphic inscriptions in Cufic became popular, with some of the finest works created between the tenth and fourteenth

[11] Crown glass was made by blowing a gather of glass that was spun until it opened up forming a disc with a characteristic "bulls-eye" or "bullion" where the pontil had been attached (Paynter and Dungworth 2011:31; Vose 1984:48; Roenke 1978: 5).

centuries (Figure 12) (Saldern 1980:146; Tait 2004:125; Vose 1984:60-64; Whitehouse 2012:52-59; Zerwick 1990:40-45). Islamic glass exerted a profound influence on the glass made in the Iberic peninsula, most of which was dominated by Muslim groups for 800 years (Frothingham 1963:13).

Figure 12. Mosque Lamp, 13th-14th century, Syria or Egypt, Museo Lázaro Galdiano (photo: Karime Castillo).

During the Renaissance, Venice and more specifically the island of Murano where glassmakers were sent since 1291 to reduce the risk of fires, became a prominent glass center. Venetian glassmakers, organized in a powerful guild, established strict rules for its members and the quality of their output. By the fifteenth century, some of the most famous glass products made in northern Italy included the *cristallo* glass (named that way for its resemblance to rock crystal) with thin walls and almost colorless achieved with the use of pure raw materials and manganese-bearing pyrolusite mineral; *lattimo*, a white glass resembling porcelain; glass with gilded and enameled decoration; and glass that imitated gemstones. Venetian glassmakers also reduced the lime content and increased the soda content in the glass, thus increasing the range of temperature in which glass could be worked, which allowed the artisans to create a rich diversity of complex designs (Figure 13) (Douglas and Frank 1972:6-7; Phillips 1981:61-62; Tait 2004:148-149; Whitehouse 2012:65-67).


Figure 13. Venetian *cristallo*: a) tazza, *ca*. 1600; b) goblet, 1575-1625; c) wineglass, 1600-1650 (Corning Museum of Glass online catalogue).[12]

The Renaissance brought more innovations to glass technology. Venetian glassmakers used canes to make several kinds of filigree glass or *vetro a filigrana*. One of the most common was *latticinio*, which used canes of *lattimo* glass. Patterns included *vetro a fili*, in which the white canes remain separate from one another (Figure 14a)*; retortoli,* in which the white stripes are twisted and sometimes include other colors (Figure 14b); and *reticello*, where the canes are superimposed producing a net-like effect (Figure 14c) (Phillips 1981:73; Saldern 1980:193; Tait 2004:168; Whitehouse 2012:68). They also developed chalcedony glass that had a marbled appearance; ice-glass with a crackled appearance achieved by plunging the hot glass into cold water and then reheating it to close and smooth the fissures (Phillips 1981:62, 73; Tait 2004:163, 170); and mirrors using the tin and mercury process, although this technique seems to have come from Germany or France (Roenke 1978:13).

[12] a) https://www.cmog.org/artwork/tazza-6?search=collection%3A7563fc0c87740ab5afcaa324598721e8&page=6; b) https://www.cmog.org/artwork/goblet-1460?search=collection%3Ae46f05e2d319ca6874db87febe36f6bc&page =37; c) https://www.cmog.org/artwork/winged-goblet0?search=collection%3Ae46f05e2d319ca6874db87febe36f6bc &page=53.


Figure 14. Venetian filigree glass: a) wineglass (*vetro a fili*), 1550-1650; b) wineglass (*vetro a retortoli*), 1550-1610; c) goblet (*vetro a reticello*), 1675-1725 (Corning Museum of Glass online catalogue).[13]

Venetian glass, which was fragile and costly to transport, became a sign of wealth and sophistication all over Europe. The utilitarian craft of glassmaking was elevated to a refined courtly art. This stimulated local production and workshops that made glass *à la façon de Venise* (Figure 15) began to appear in Austria, Slovenia, Germany, the Low Countries, Spain, France, England, and Sweden. Many of the workshops producing Venetian-style glass were established by Venetian glassmakers or had some Muranese artisans working in them despite the fact that it was illegal for glass artisans to emigrate from Murano (Barovier Mentasti 2003:27; Phillips 1981:75; Tait 2004:163, 172; Whitehouse 2012:71-74).

[13] a) https://www.cmog.org/artwork/goblet-706?search=collection%3Ad69af522da4e085319fa305a03d8e87d&page=0; b) https://www.cmog.org/artwork/tazza-24?search=collection%3A9229d2965e4c6bb727fb321a1b18d68e&page=6; c) https://www.cmog.org/artwork/goblet-727?search=collection%3Ad4ac6b442b13e4327b8def308ae8c9c2&page=5.

Figure 15. Glass *à la façon de Venise* from Catalonia, 1590-1650, Museu del Disseny, Barcelona (photo: Karime Castillo).

Another important glass center emerged north of the Alps in Bohemia, which became famous for its cut and engraved glass. Unlike Venetian *cristallo*, which was too soft for any type of deep-cutting, the hardness of potash glass, made with local wood ashes, permitted the use of true cutting techniques and was easier to engrave. Using new methods to purify the potash and adding manganese as a decolorizer, Bohemian glass artisans were able to make a thick and fairly clear glass that enhanced the decoration (Figure 16). Later innovations to the glass formulas, such as the addition of chalk, further improved the suitability of the glass for cutting and wheel-engraving. Bohemian glass artisans also adopted techniques like gilding and enameling, and towards the end of the seventeenth century, they developed a recipe to make ruby gold glass by adding gold chloride to the batch (Barovier Mentasti 2003:27-28; Douglas and Frank 1972:18; Morley-Fletcher 1984:100-101; Tait 2004:179-182; Whitehouse 2012:75-77).

Figure 16. Bohemian glass goblet, *ca*. 1690, Victoria & Albert Museum (Board of Trustees of the Victoria & Albert Museum).[14]

In England, a new type of dark bottle that protected its contents from light was developed in the mid-seventeenth century. This bottle was made of dark green, almost black, glass with a narrow neck that enabled it to be sealed, a globular body, and very thick walls (Figure 17a). Its durability made it an ideal container for the storage and shipment of liquids because few broke during the journey, and it turned England into the leading supplier of bottles for the Western world for more than a century (Dungworth 2012:37; Morley-Fletcher 1984:105; Whitehouse 2012:78; Zerwick 1990:63). Around this time, cork stoppers became extensively used to seal glass bottles (Douglas and Frank 1972:165). Another novelty in glass production that happened in the second half of the seventeenth century was the introduction of a new type of crystal-clear leaded glass by George Ravenscroft (Figure 17b). Lead crystal glass, also known as flint glass, was both strong and superbly clear, but it could not be worked as thinly as Venetian glass. Nevertheless, British glassmakers began to create a style of their own, manufacturing sober and

[14] http://collections.vam.ac.uk/item/O249507/goblet-and-cover-unknown/.

constrained forms that acquired popularity in Europe towards the end of the seventeenth century (Barovier Mentasti 2003:28; Douglas and Frank 1972:14-15; Morley-Fletcher 1984:106-107; Tait 2004:182-184; Whitehouse 2012:81). In the Netherlands, a new decorative technique emerged called stippling, in which a scene was composed by making dots with a diamond-pointed tool, which worked great on lead crystal glass (Tait 2004:184; Zerwick 1990:65-66).


Figure 17. British glass: a) dark green glass bottles 1650-1820, Real Fábrica de Cristales de la Granja; b) Ravencroft’s lead crystal glass, 1675-85, Victoria & Albert Museum, London (photos: Karime Castillo).

In the eighteenth century, large windows and chandeliers (Figure 18) became prominent features of architecture and interior design (Whitehouse 2012:82). France, where a Royal Company of glass was active since 1665 (Melchior-Bonnet 2001:40), became a major producer and exporter of fine mirror glass of large dimensions. Large plate glass sheets[15] larger than 80 $in^2$ were made at St. Germain for the first time in 1688 by glassmakers who later founded the workshop of St. Gobain, which became the greatest producer of mirrors in Europe (Melchior-Bonnet 2001:55; Roenke 1978:9, 15; Sennett 2008:100). The French glass industry had lagged behind the Italian, Bohemian, and English industries in the making of decorative glassware, but this changed towards the end of the eighteenth century after the establishment of the Baccarat factory in 1765 (Curtis 1992:49; Douglas and Frank 1972:20). Bohemian glass also acquired a

[15] Plate glass is made by pouring molten glass onto a metal casting table and spread evenly using a roller running on metal guides (Roenke 1978: 9).

lot of popularity all over Europe during this century, surpassing the Venetian competition. European elites began to prefer Bohemian glass at their tables, stimulating some glass workshops to produce glass *à la façon de Boheme* and the opening of permanent trading centers in many European cities, including port cities like Cadiz and Seville from where Bohemian glass products were sent to the New World (Frothingham 1963:58; Langhamer 2003:40-43).

Figure 18. French chandelier, 18th century (Metropolitan Museum of Art online catalogue).[16]

The Industrial Revolution shook the glass industry in the nineteenth century: starting in 1899 several versions of the Owens Bottle Machine (Figure 19a) were developed that allowed the process of bottle-making to become fully automatized (Walbridge 1920:55); mechanical presses were developed in the 1820s in the US and soon spread throughout Europe; the silvering method for mirrors was invented in 1835 (Roenke 1978:13); cast-iron rollers tolerant of constant high heat developed in the 1840s allowed for the making of large panes of rolled glass sturdy enough for construction (Sennett 2008:111); machines were devised to produce repetitive acid-etched decoration that imitated engraving; and tempered or "thoughened" glass was developed

[16]https://www.metmuseum.org/art/collection/search/200540?searchField=All&sortBy=Relevance&ft=french+chandelier&offset=0&rpp=20&pos=12.

around 1875 (Roenke 1978:13). The production processes to make glass containers and large-sized sheets of glass also became fully mechanized and were gradually adopted from the 1880s onward. These innovations reduced costs and increased productivity, allowing the mass production of utilitarian glass. However, not all glass production became industrialized. In the last decades of the nineteenth century, artists and designers began to work with glass; this can be seen in the numerous works created by Art Nouveau artists and designers (Figure 19b) (Barovier Mentasti 2003:30; Whitehouse 2012:86, 96; Zerwick 1990:87, 93).

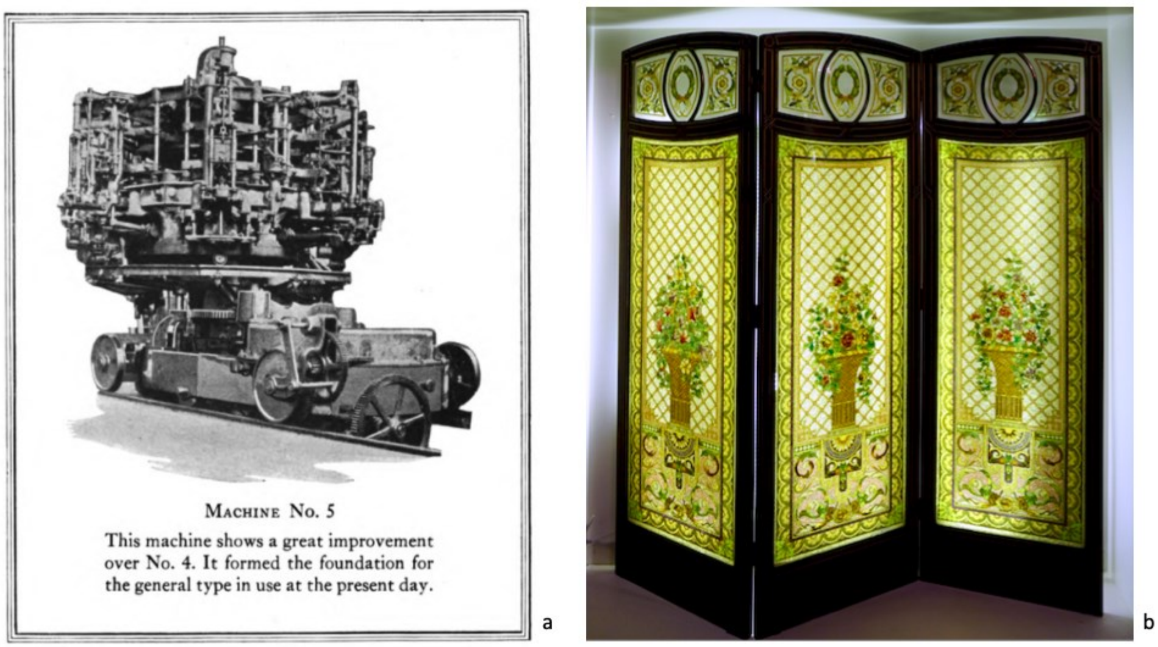



Figure 19. The glass industry at the end of the 19th century: a) Owens Bottle Machine No. 5 (Walbridge 1920:70); b) Three-panel screen, Francesc Vidal, Jevellí, *ca*. 1899, Museu del Modernisme Català, Barcelona (photo: Karime Castillo).

In the twentieth century, glass continued to be made using traditional techniques and artists kept using it as a medium for a variety of artworks. At the same time, changes in the composition, manufacture, and uses of glass came in rapid succession and continue to do so in the twenty-first century. Borosilicate glass commonly known as Pyrex™, safety glasses such as tempered and laminated glass, optical fiber widely used in telecommunications, ultra-low-expansion silica mirrors used in telescopes, defect-free glass for liquid crystal displays, and Gorilla Glass™ on smartphones, are just a few examples of these innovations (Whitehouse 2012:120).

## 2.3. The study of Archaeological Glass: Challenges and Opportunities

The study of archaeological glass comes with particular challenges. For starters, it is not a material that is usually considered a priority in the training of an archaeologist, hence when confronted with a glass collections, it is usually approached in the same way as a ceramic collection. In many ceramic typologies, particularly those based on the type-variety method (*e.g.*, Fournier García 1990), the first sorting is usually based on the paste (*e.g.*, earthenware, stoneware, porcelain), by looking at characteristics that, for the most part, are visible to the naked eye such as its color, porosity, and the inclusions present in it, all of which provide clues about the raw materials used (*e.g.*, temper, type of clay) and technology (*e.g.*, reduced or oxidizing firing conditions). Further sorting is done by progressively looking at other attributes within each group such as surface treatment, shape, and decoration. The main problem with applying this approach to a glass collection is that the first step of the sorting is not straight forward. The things that need to be identified in order to determine the type of glass at the most basic level, mainly the raw materials used to make it, are not discernable to the naked eye. Like ceramics, glass is a man-made material created through the combination of different materials that are transformed into a new product through a heat treatment. However, in ceramics, some of the components sinter while others remain unchanged (Pollard and Heron 2008:117) and can be identified using a polarized light microscope (PLM) and in some cases they are discernible with a magnifying glass. In the case of glass, all, or most of the components melt into a fairly homogeneous material that has the characteristics of the glassy state. The presence of impurities in the silica source such as iron, or the addition of colorants, decolorizers, or opacifiers will have very similar effects in the appearance of all types of glass, regardless of the raw materials used to make it. While it is true that a colorant may act differently depending on the chemical composition of the glass in which it is introduced, for instance, the presence of a heavier alkali such as potassium oxide will make the glass appear darker than one made with sodium oxide (Henderson 2000:30), a darker color does not necessarily imply that the glass is of the potash kind. The glass composition of two bottles that look the same to the naked eye can be radically different, representing two distinct types of glass. The only way to distinguish natron glass, from plant ash glass, from lead glass, is through the identification of its constituent materials, and currently, this can only be achieved through scientific analysis with the application of characterization techniques such as X-ray fluorescence (XRF), electron (SEM-EDS/WDS), and mass spectrometry techniques (ICP-MS) among others (Henderson 1989:32).

A further difficulty comes from the material's fragility. Just like ceramics, glass objects are often found broken, but the sherds tend to be a lot thinner and smaller than ceramic sherds, and the conchoidal fracture characteristic of glass produces clean edges that look very similar in every sherd. Finding two glass pieces that fit together, like is often done with ceramics, can be much harder when it comes to glass. This is heightened by the fact that decoration is not a frequent attribute in most utilitarian glass objects. In addition, deterioration processes affecting glass can dramatically change its original appearance, as well as its composition.

Nevertheless, archaeological glass has an extraordinary research potential that has attracted the attention of scholars from different disciplines. Since standard practice varied considerably with time and place, by studying the chemical composition of the glass we can obtain information about dating, provenance, and technology (Freestone 1991:39-46; Henderson 1985:270-286; 2013:23, 54, 56; Moretti and Hreglich 2013:28-32). The following discussion will focus on the potential of glass studies in the Americas, with an emphasis on Mexican historical archaeology.

The transfer of glass technology to the New World is one of the areas in which the study of glass through scientific methods is very promising because little is known about how the first glass artisans in New Spain assimilated the technology to local conditions, resources, and practices. In this sense, the analysis of archaeological glass collections from Mexico is necessary to understand the processes of adoption, adaptation, and assimilation of this foreign technology in a land where the material had never been made before.

Glass is also an interesting material in terms of its potential in the mediation of social relations. As an imported product from Europe, it was primarily linked to Spanish identity and may have represented a symbol of distinction, at least at the beginning of the Colonial period. As such, its abundance or absence in different kinds of archaeological contexts, such as colonial Spanish towns and indigenous settlements, may provide information not only about the status, identity, and aspirations of different sectors of the population, but also about the extent to which this material was adopted by people who had never seen it before. Identifying the context in which glass production started and evolved, and the actors involved in these processes, can shed new light as to how the guild system, which permeated most craft production in New Spain, contributed not only to restrict access to the material, but also, to define its symbolic value throughout the colonial period and how this has influenced consumption practices. The analysis of differential access to certain goods can provide important information on the role material culture plays in the perpetuation of inequality. Exploring how objects, technologies, and materials were used as social markers, and how different sectors of the population used them to negotiate their own social standing are crucial in elucidating the representational role that material culture has played in daily life, as well as how the colonial social structure was ordered and hierarchized, and the ideology that sustained it.

Archaeological glass can also provide insights into the industrialization processes of the nineteenth century, the effects of mass production in society, and the movement of commodities as products were imported and exported. Glass can also be studied as part of more specific research subjects as varied as the history of medicine, pharmacy, laboratories, optics, artificial lighting, alcoholic and carbonated drinks, foodways, games, ritual practices, personal adornment, cosmetics, and perfumes to name a few.

## 2.4. The Study of Glass in Mexico

The earliest works about glass in Mexico, written mostly by historians, art historians, and some anthropologists, are brief accounts based on historical documents exploring the establishment of the first glass houses in Mexico, particularly in the city of Puebla. Romero de Terreros (1951; 1923), for instance, dedicates short sections to early glass production in New Spain in his books on viceregal art; Sarmiento (1948) includes a chapter on the first glass workshops in Puebla in a historical account of the city; whilst Manuel Toussaint (1974) writes a brief account on glass from Puebla and questions the kind of glass that should be considered artistic in a book about Mexican art of the Colonial period. Ross (1952) presents a brief ethnographic account of glassblowing in Mexico in a book about Mexican art and crafts, while Alfonso Caso (1958) presents the products of the small glass-blowing workshops in Jalisco, Texcoco, and Mexico City as examples of mestizo handcrafts representing cultural synthesis.

José Rogelio Álvarez (1969) traces the origins and follows the development of glass production in the four places where the tradition continued until the twentieth century: Puebla, Mexico City, Texcoco, and Guadalajara; soon after, he published a volume specifically on the glass blowing tradition of Guadalajara (Alvarez Noguera 1970). Teresa Castelló (1971) focused on the presence in Mexico of glass from the Spanish royal factory of glass of La Granja de San Ildefonso and its influence on Mexican glass production. A later publication by Flores Barba (2007) investigates the history of glass in Jalisco tracing it back to the early nineteenth century, while Vidales Giovannetti (2009) wrote a succinct history of glass in Mexico focused mostly on Puebla.

Glass is often discussed in publications about Mexican popular art. Dörner (1962) briefly discussed glassware production in Mexico City, Puebla, and Guadalajara, noting also the making of glass miniatures, as well as the use of glass beads in local costume and jewelry in a book about Mexican folk art. In his book about handcrafts, Espejel (1972) presents a brief overview of the different methods glass artisans use across Mexico. Martínez Peñaloza (1972, 1981) includes a brief section dedicated to the history and production of Mexican glass in Puebla, Mexico City, Jalisco, and Nuevo León, as well as a brief description of the process of glassblowing in his books on crafts from Mexico. Rubín de la Borbolla (1974) includes information about the beginnings of the glass industry in Puebla during the Colonial period in his book on Mexican popular art. Two entries on twentieth-century glass artisans are included in a book showcasing masters of Mexican folk art (Fernández de Calderón et al. 2001), one on Jaime Camarasa Molas, who became famous in Jalisco for his red glass; and another one on the glass workshop Carretones in Mexico City. More recently, in a book showcasing the collection of the Museo de Arte Popular in Mexico City, Melo de Sada (2006) discusses the different techniques used to work glass, while another publication focused on the production of Christmas glass spheres in Chignahuapan, Puebla (Vera Muñoz et al. 2015).

Other publications on Mexican glass have been generated as part of exhibitions and the establishment of a glass museum. The exhibit showcasing the history of glass in Mexico presented at the Museo Nacional de Historia in the late 1980s in Mexico City (1989) was one of the products of extensive historical research conducted by Miguel Angel Fernández as part of a project to create a museum dedicated to glass in the northern city of Monterrey. This is the city where Vitro, a major industrial glass factory in the country, stands today. The research was compiled in a book (Fernández 1990) that offers a thorough historical account of the industry, from the arrival of glass to the Americas and the establishment of the first colonial glassworks, to the development of industrial glass during the nineteenth century, particularly in the north of Mexico. Museo del Vidrio (2009), opened in 1992 aiming to rescue the history of glass in Mexico and to promote the artistic production using this material. A catalogue of the museum's collection explores the origin of glass, its development in Mexico, the different techniques for its manufacture, and its use as an art medium (Ulloa 1999). Additionally, the catalog of another exhibit about the presence in Mexico of glass from Spain's royal factory of glass in La Granja, presented at Museo Franz Mayer in Mexico City, contains studies that explore the movement of glass between Mexico and Spain (Pablos et al. 1994).

Researchers have also conducted studies that focus on particular types of glass, such as beads, jewelry, and window glass. Castelló and Mapelli Mozzi (1998) discuss the use of tiny glass beads known as *abalorio* or *chaquira* in Mexican beadwork. The use of glass beads in clothing and jewelry in Mexico has also been investigated by Andreia Martins Torres (2016), who additionally investigated the resignification that glass necklaces from the Zapotec community San Pedro Quiatoni undergo when exhibited in museums (Martins Torres 2018b). Art historians (Echegaray and Castillo 2004) have studied the history of stained glass windows in Mexico from colonial times to the present, and the art journal Artes de Mexico dedicates a volume to the stained glass windows of Mexico City (Chauvin 2009). In addition, Moreno Corral and Luna Aguilar (1999) have investigated the use of glass in optical instruments in colonial and early Independent s Mexico.

There are also some studies that explore the development of industrial glass in Mexico during the twentieth century. A report by González Tapia (1954) focuses on the industrial production of tableware glass, while Francisco de la Torre (1994) briefly discusses the expansion of the industry in central Mexico in the nineteenth and twentieth centuries. Vidales Giovannetti (2003) included a section on glass in a book about containers that explains some industrial manufacturing processes and provides other technical information useful for the description of glass containers. Other scholars have done research on how the development of industrial glass in the north of Mexico and the establishment of major glass factories were linked to the emergence of the beer industry (Corrales 2010). In fact, many publications that discuss the history of alcoholic beverages, and for the case of Mexico those related to the beer industry, often include sections about industrial glass (Gauss and Beatty 2014; Reyna and Krammer 2012). Recent historical studies have greatly advanced our knowledge of the history of glass in Mexico. Peralta Rodríguez (2013) investigated the trading centers and workshops of glass in the viceregal capital, and the raw materials used in them (Peralta Rodríguez 2018). He has also studied the production of specialized glass in Mexico City, including ophthalmic glasses (Peralta Rodríguez 2004, 2005) and pharmaceutical glass (Peralta Rodríguez 2014). More recently, Martins Torres (2019a) conducted extensive historical research about the import of glass beads into New Spain and other parts of the Spanish Empire as well as the production of glass in colonial Mexico with a particular focus on beads. She provides an in-depth discussion of the history of glass production in the Spanish colonies in Americas, with a particular emphasis on Mexico but covering also those in South America and the Philippines. Her work represents the most comprehensive historical study of glass production in the Americas conducted so far.

In archaeology, glass is often mentioned in reports, but is not discussed in depth as a material (*e.g.*, Amaro Robles et al. 1996; Hernández Pons et al. 1998; López Cervantes 1982; Martínez Magaña 1998). However, there are many archaeologists that have taken a closer look at glass artifacts and have made contributions to its study. An article from the late 1960s that examined an assemblage of nineteenth and early twentieth century glass bottles found in Magdalena de Kino, Sonora, in the north of Mexico, as part of the excavations carried out to find Father Kino's remains represents one of the earliest studies of archaeological glass in Mexico (Fontana 1968). López Cervantes (1979) compiled a document with information on historical sources useful for the study of colonial glass in Mexico, as well as, a general bibliography of glass throughout history and around the world to support the study of archaeological glass (López Cervantes 1980). Judith Hernández completed one of the first studies of archaeological glass from Mexico City in 1980; her report includes a catalogue of glass from Ex-convento de San Jerónimo in Mexico City, and a relative chronology of the forms present in the site (Hernández Arana 1980). A short section on glass, focused mostly on early twentieth century glass production, is included in a book about industrial archaeology in Mexico (Saldívar 1983).[17] Deagan (1987) dedicated sections to archaeological glassware and glass beads in her book on artifacts of the Spanish colonies. In this book, she proposed a typology of glass from different

[17] The chapter contains some errors regarding the beginnings of glassmaking in Mexico, for instance, it argues that glass production in Mexico began in the eighteenth century (Saldívar 1983: 225).

production centers around the world that can be found in colonial America. Kelly (1992) conducted extensive research into the trade beads that circulated in Mexico, particularly during the Contact period.

There are four bachelor (*licenciatura*) theses from the National School of Anthropology and History (ENAH) dedicated to archaeological glass from Mexico City. The most recent one proposed a methodology for the restoration and the conservation of archaeological glass depending on the type of context where it is found, whether it is a dry, humid, saturated, or maritime environment (Almaguer Rosales and Arteaga Márquez 2010). A second thesis discusses the glass recovered from the Antiguo Palacio de Odontología de la UNAM and proposed a typology based on form, function, and manufacturing method and recommended some practices for excavating, cataloguing, packing, and storing archaeological glass (Alvízar Rodríguez 2007). The third thesis focuses on the glass recovered from two sites in the historical downtown of Mexico City, the Ex convento de la Encarnación and the Antiguo Estanco de Tabaco, and suggests its possible use as a dating tool and as an indicator of social status (López Ignacio 2000); two publications resulted from this work, an article on the presence of glass in New Spain (Salas Contreras and López Ignacio 2007) and a book based on the thesis (Salas Contreras and López Ignacio 2011). The fourth thesis uses glass bottles for alcoholic beverages to reconstruct the activity areas of a nineteenth century saloon (Nieto Estrada 1996).

Research about industrial glass in Puebla was carried out by Citlalli Reynoso Ramos (2005; 2010), who studied bottles from the old factory of mineral water La Superior. Glass marbles recovered in archaeological excavations in the historical downtown of Mexico City allowed researchers to also explore childhood and games in colonial Mexico (Cedillo Vargas and Lechuga García 2009). Other scholars used archaeological material from the Casa del Apartado, to study aspects of colonial metallurgy and glass production in Mexico City (Peralta Rodríguez and Alvízar Rodríguez 2010). Martins Torres (2018a) has explored the use of glass beads by colonial women through the study of glass beads recovered from excavations at the Convento de la Encarnación, as well as the incorporation of glass beads in an indigenous burial found in the excavations of the colonial church of San Gabriel Tacuba (Martins Torres 2020), both located in Mexico City. The presence of glass beads of European origin in indigenous burials in colonial Nejapa, Oaxaca has also been recently investigated (Konwest et al. 2020).

While the aforementioned publications have increased our knowledge about the development of the glass industry in Mexico, especially from a historical perspective, and some researchers have proposed typologies that have helped archaeologists categorize the glass found in excavations to a certain extent, they all have a major limitation: the chemical composition of glass is not taken into consideration.[18] This is an important hindrance because, as mentioned above, the use of different raw materials can indicate different technological traditions, and it is the only way to evaluate technological changes and adaptations in glassmaking through time. Without scientific analyses of the chemical composition and weathering (state of conservation), of an archaeological glass collection, visual observations and other subjective types of examination offer little in terms of classification; only sorting materials by manufacturing technique, form and function, color, and decoration if present. With complete or partially complete artifacts and diagnostic sherds, it is possible to reach an adequate degree of understanding of a collection and even make significant interpretations. This is particularly true for industrial glass, where manufacturing technique can provide solid grounds to date and

[18] The thesis by Lopez Ignacio (2000) as well as the published article and book based on her thesis research (Salas Contreras and López Ignacio 2007; 2011) identify different types of glass, however classified by their visual characteristics and sound. No scientific evidence is presented on the chemical composition of the glass assemblage discussed, which is crucial to scientifically identify variability in glass as done in this research (see Chapter 9).

correctly identify an artifact, as demonstrated by the work of Reynoso Ramos (2005; 2010) and Alvizar Rodríguez (2007). Moreover, chemical composition becomes less significant in terms of identifying a technological tradition in the case of twentieth century traditional blown-glass[19] because most glassblowing workshops began to rely on recycled industrial glass as the main raw material rather than on the production of raw glass. Today, the traditional glassblowing workshops in both Jalisco and Puebla rely exclusively on recycled glass (Castillo Cárdenas 2016).

To understand the transfer of this technology into the New World, and its development afterwards, the scientific study of archaeological glass collections is pivotal. To this date, there are no publications regarding the composition of archaeological glass from Mexico. López and Martínez (2012) discuss some of the properties of glass and historical aspects of its production in Mexico in a book intended for the general public, which has also been used by some archaeologists. However, the simplified presentation of the subject matter in this book has led to several misunderstandings and misinterpretations. One of them is the idea that glass of different compositions such as sodic, potassic, and lead glass,[20] can be distinguished from each other based on sound attributes and visual characteristics such as the presence of bubbles or a hazy appearance. This whole approach is biased and leads to incorrect statements and interpretations. Glass composition cannot be determined by observations with the naked eye nor through optical microscopy alone, much less through the sound a glass object makes. Not only can glasses with

[19] Unless the focus of the research is on the different formulations of industrial glass.

[20] There are many more types of glass compositions other than these three, and even if a study is limited to those used before the twentieth century, this oversimplification ignores the wide variety of glasses used in Antiquity and the Middle Ages such as: plant ash glasses, mixed-alkali glasses, natron glass, wood ash glasses, soda-alumina glass, potassium-silica glass, potassium-lime glass, lead-barium oxide glasses, lead potassium glass, and lead-soda glass among others (Henderson 2013). Moreover, the scientific literature on archaeological glass composition is profusely abundant and needs to be taken into full consideration by anyone attempting to discuss glass production and technology.

completely different compositions may look exactly the same, but this incorrect notion totally ignores other factors that may contribute in the appearance of glass, notably weathering. The deterioration processes undergone by archaeological glass can drastically alter its visual characteristics as well as its structure, and can be responsible of a dull or hazy appearance. In addition, the composition of corroded glass can be significantly different from the original composition of the glass, given that many of these processes involve the leaching of alkalis that can then react with the superficial layers of the glass (Bellendorf et al. 2010). In addition, a dull appearance on glass can be produced by any process that involves contact with the glass surface during its manufacture, which changes its natural polish (Frank 1982:44). The amount of bubbles in glass is also not necessarily related to the composition. Bubbles in glass are formed by the gasses released during the chemical reactions and transformations that take place during the melting of any glass (Moretti and Hreglich 2013:31). Bubbles in a finished product, also called seeds or blisters if they are large, usually mean that the glass was used before it had enough time to thoroughly melt and release those gases. Bubbles can also be formed by careless or inexperienced workmanship, in which case air gets enveloped as the glass is gathered to work it (Roenke 1978:25). Glass composition cannot be determined in terms of how brilliant or hazy the glass appears or the presence of bubbles in it. The only way to distinguish different glasses based on their raw materials is through the scientific analysis of their chemical composition, which at present, can only be done through a set of characterization techniques such as X-ray spectrometry or mass spectrometry that identify elemental and chemical structure.

Another important misconception derived from the book by López and Martínez (2012) is the idea that glass is made of clay (*arcilla* in Spanish). It is also possible that this misconception derives from the fact that, in materials science, glass is considered under the broader category of ceramic materials. But glass is most certainly not made of clay. Technically speaking, clays and sands are defined in terms of grain size. Clay is a material where the minerals are of very small size (< 2 microns) whereas in a sand, mineral particles are coarser (between 0.062 and 2 mm). However, this definition does not refer to the composition. Sand can be non-siliceous (*e.g.*, calcareous or carbonate sand), or silica-rich (*e.g.*, quartz sand), but the term "sand" without adjectival modifiers tends to imply the siliceous composition (Pettijohn et al. 2012:1). On the other hand, clay minerals are hydrous phyllosilicates or layered aluminosilicates containing primarily aluminum (Al) and silicon (Si) (Fahrenholtz 2008:111, 113). Glass, apart from rare and very specific examples,[21] is made with silica-rich sand. A broader discussion on silica as the main raw material for glass is presented in Chapter 8.

Only one other study has been done to characterize historical glass from Mexico through scientific methods, a bachelors thesis in physics from Universidad Nacional Autónoma de México (UNAM) that presents the results of the analysis of a glass collection from a nineteenth century hacienda in Yucatan (Cadena Irizar 2018). No studies on archaeological glass from Mexico City nor Puebla, the two main production centers of glass in the Colonial period, or from any other city in the country have been published. This dissertation provides, for the first time, compositional data on the historic glass from these two cities. The scientific study of archaeological glass in Mexico is still at its infancy and this project seeks to contribute to the development of a multidisciplinary approach to archaeological research and further new and transformative scholarship.

[21] Examples include phosphate and boron glasses.

# 3. THEORETICAL PERSPECTIVES FOR THE STUDY OF COLONIAL GLASS PRODUCTION

Understanding the processes of the adoption and adaptation of glass technology in New Spain and interpreting the role that glass played in colonial society is a complex endeavor. Firstly, it is necessary to recognize the colonial context within which these processes took place, as well as, the different groups involved. It is important to analyze the intentionality of both producers and consumers in the making and use of glass objects respectively. Identifying who the manufacturers were, under which circumstances the production process took place, and what individual or collective needs these objects fulfilled, is necessary to discern the technological choices that determined the development of this industry in colonial Mexico. These issues can be better understood when analyzed within a theoretical framework integrating historical archaeology, approaches to the study of colonialism and postcolonial theory, and the anthropology of technology. Most of these approaches are assimilated within the inter- and multidisciplinary field of material culture studies, a discipline that examines the relationship between people and materials by analyzing a variety of aspects involved in this relationship: from the making, exchange, and consumption of things, to the nature and experience of materiality, as well as the history, preservation, access, and interpretation of objects (Tilley et al. 2006:1). However, a perspective that allows for the integration of archaeology and scientific analysis is also paramount for this research. Archaeological science has developed into a discipline that integrates rigorous scientific analysis from the physical and biological sciences and engineering, within an archaeological framework focusing on the study of past societies, bringing together skillsets from both sides – the sciences and the humanities – to enquire the past.

## 3.1. Historical Archaeology in Mexico

Historical archaeology is a multi- and inter-disciplinary research field that focuses on the social processes associated with the emergence and consolidation of capitalism, modernity, and globalization that occurred worldwide after the European expansion that began in the fifteenth century (Charlton et al. 2015; Deetz 1991:1; Fournier García 1998:89; Little 2007:23; Orser 1996:27). In Latin America, archaeology has been associated from the beginning with the study of the prehispanic past and for a long time, any research about the material culture of the colonial period and beyond was done primarily by art historians and architects (Funari 1997; García Bárcena 2002:12-15). In Mexico, archaeology has been linked to the interests and agenda of the state and its main purpose has been to reaffirm national identity and ideology (Fournier García and Miranda-Flores 1996:440; Mastache and Cobean 1988:39). Mexican archaeology has also responded to economic pressures and political interests that focus on tourism, where monumental sites that can be opened for visitors are considered more relevant (Fournier García 2003:18; Gándara 2002:12; 2003:11-12). For these reasons, prehispanic archaeology has received more support from the government and other institutions and much of the initial archaeological research pertaining to the Colonial and Independent periods remained unpublished (Fournier García 1999:83; 2003:18; Hernández Pons 1996:11).

The interest in historical archaeology in Mexico derived initially from architectural restoration work in which archaeology played a supporting role (Juárez Cossío 1989:13). Eduardo Noguera (1934) was one of the first archaeologists to focus on colonial materials by analyzing the change in technology and style of the colonial ceramics recovered from the excavations at Templo Mayor. More research on colonial ceramics, particularly on majolica, was carried out in the late 1960s by Goggin (1968) and Charlton (1968). Around the same time, the subway system was built in downtown Mexico City and the abundant colonial remains that were found became a subject of study (Fournier García 1999:80; Fournier García and Miranda-Flores 1996:441; Gussinyer 1969:90). From the 1970s onward and linked to the rapid growth of the Instituto Nacional de Antropología e Historia (INAH), research in historical archaeology, ethnoarchaeology, and to a lesser extent industrial archaeology took off in Mexico (Gándara 2003:13; López Aguilar 1988:707), while underwater archaeology research did so in the 1990s (Fournier García 2003:19).

Historical archaeology often comes as part of salvage archaeology projects (Escobedo Ramírez 1995; González Rul 1988; López Palacios et al. 1996) and continues to be linked to architectural restoration (Fernández Dávila and Gómez Serafín 1998) as well as to the adaptation and reassignment of historical buildings to new purposes (Hernández Pons 1987; 1997; Hernández Pons et al. 1998; Juárez Cossío 1989; Moreno Cabrera 2000; Reynoso Ramos 2006; Salas Contreras 2006). However, due to time and budget constrains the materials are rarely analyzed in detail and are often discarded because of the limited storage space. These salvage archaeology projects generally result in finds reports with descriptions and/or catalogues of materials. In these reports, interpretations of the materials are often limited and only few of them turn into publications; those that do are rarely distributed abroad. In the case of projects focused on architectural restoration, historical archaeology tends to be subordinated to reconstructing a building’s history (Fournier García 2003).

Nevertheless, since the 1970s, there have been projects focusing on the socioeconomic processes that happened after the Contact period and the interest in the field has grown (Fournier García 1999:79; Fournier García and Miranda-Flores 1996:443). Initially, many of the projects focused on colonial ceramics (Charlton et al. 1995; Deagan 1987; Fournier García 1990; González Rul 1988; Hernández Pons et al. 1988; Lister and Lister 1982; López Cervantes 1976; Müller 1973; Müller 1981). Interest in this material has grown steadily and continues to be the subject of multiple research projects today (Charlton and Fournier 2010; Charlton et al. 2007; Forde 2017; Fournier García 1997; Fournier et al. 2009; Gómez Pastor and Fournier 2001; Hernández Sánchez 2019; 2012; Rodríguez-Alegría 2008). However, historical archaeologists have expanded their scope to cover a large variety of subjects, including: culture contact (Deagan 1998; Whittington and Workinger 2015), change in colonial Mesoamerica (Alexander and Kepecs 2018; Gasco 1993, 2005; Hofman and Keehnen 2019; Kepecs and Alexander 2005; Palka 1998, 2009; Zborover 2015a), identity and status (Fournier García and Charlton 1996; Fournier García and Zavala Moynahan 2014; Gasco 1992; Voss 2012), consumption (Awe and Helmke 2019; Fournier García 1997; Rodríguez-Alegría 2016; Zeitlin and Thomas 1997), labor and life in haciendas and ranches (Fournier García and Brown 2011; Fournier-García and Mondragón 2003; Hernández Álvarez et al. 2020; Hernández Álvarez and Zimmermann 2016; Jones 1981; Juli 2003; Meyers 2005; Meyers and Carlson 2002; Newman 2017; 2014; Sweitz 2012), foodways (Biskowski 2015; Newman 2010; Reynoso Ramos 2008, 2015; Rodríguez-Alegría 2005b), religion and ritual (Miller and Farriss 1979; Palka and Sánchez Balderas 2015; Zeitlin and Palka 2018); health and mortuary practices (King and Higelin Ponce de León 2017; Reynoso Ramos and Ocaña del Río 2005; Warinner et al. 2012); gender (Fournier García 2018; Voss 2008); agrarian ecology (R. T. Alexander et al. 2018; Alexander 2018); and the African diaspora in Mexico (Barquera et al. 2020; Eschbach 2019; Fournier García and Charlton 2008; Gallaga Murrieta 2009; Gallaga Murrieta and Tiesler 2013; Price et al. 2006), to name a few.

The twenty-first century has also seen an increase in global approaches from multiple disciplines to the study of the Early Modern and Modern periods and historical archaeology has been uniquely positioned to contribute to these studies by bringing the material dimension into the discussion. Many historical archaeologists working in Latin America are framing their research in the context of Early Modern Spanish Colonialism and the global connections that developed from the 1500s onward (Montón-Subías et al. 2016). These global approaches not only situate colonialism within a larger historical framework, but also make it possible to compare different colonial experiences in particular localities under Spanish rule, as well as, under other imperial powers (Montón-Subías et al. 2016:5). Archaeological studies in Mexico conducted from a global perspective have increased with the growth of maritime archaeology and include research on transatlantic trade (Carrillo Márquez 2018; Junco and Trejo 2016; Luna Erreguerena 2013), and the Manila Galleon trade (Fournier García 2014; Fournier and Bracamontes 2010; Fournier and Junco Sanchez 2019; Junco 2010, 2015, 2018; Junco Sanchez et al. 2019; Kuwayama 1997; Priyadarshini 2018; Von der Porten 2019).

### 3.2. Archaeology of Colonialism and Postcolonial Theory

The study of colonialism in Mexico has been achieved through different theoretical perspectives. One of the frameworks that has been widely adopted by archaeologists since its inception in the 1960s is world-system analysis (Orser 2009:253). World-systems theory, underlining social systems beyond the boundaries of individual societies or nations (Shannon 1989:20; Wallerstein 2004), has provided some historical archaeologists in Mexico a theoretical framework to evaluate colonial sites and material culture from more global or macro-regional point of view (Alexander 1999; Fournier García 1999:80; Heath-Stout 2019; Kepecs 2005; Sweitz 2012). This perspective departed from the notion of national states as units of analysis, to consider a broader spatial unit defined in terms of economic interdependency between center and periphery, instead of geographic, political, or cultural parameters (Wallerstein 2004:16). What made this perspective attractive for many archaeologists is that it considers multiple levels of social, political and economic relations, which allowed for the study of interactions at different levels; it also considered that any processes and units formed within the world-system were not static, but in continuous formation and reformation according to the relations between its parts (Peregrine 1992:2,4).

However, world systems theory has been criticized for being a markedly top-down approach in which exploitation is always unidirectional, and thus, it only provides a partial analysis of the situation (Gasco 2005:71). Not only are dichotomous terms like center/periphery or developed/underdeveloped largely outdated (Murray and Overton 2015:38; Orser 2009:255), but world-systems models also fail to accommodate local agency and negotiated power relations (Stein 2005:29), which without any doubt played an important role in the social, economic, and political transformations that occurred in the Colonial period. As Leone and Potter (1988:4-5) argue, world systems theory, being a goal-directed perspective, fails to take into account failure, irrationality, and cultural survival; it is also limited in terms of understanding indigenous cultures, and in its awareness of how the present operates in the past. Nevertheless, some researchers, who are aware of the shortcomings of this perspective, use modified versions of this approach to explore long-term history and large-scale geographical areas (Orser 2009:263).

An alternative to exploring long-term history and large-scale geographical areas are network perspectives. Networks are conceptualized as a collection of points or nodes with connections between them represented by lines or links. Network analysis makes it possible to consider relationships between entities, whether these are people or objects, within a given space and at different scales, taking into account the temporal dimension (Knappett 2011:10, 38-39). Importantly, network analysis emphasizes the connections between socio-spatial entities however they are defined in their particular sociocultural context instead of employing the center/periphery dichotomy (Orser 2009:263). However, network analysis is not a comprehensive method and there can be many instances in which a network model will not provide a satisfactory explanation. For those cases other methods or models can be used in conjunction with network analysis (Knappett 2011:32). While the use of network analysis in archaeological studies in Mexico has been predominantly applied to the Prehispanic period (Golitko and Feinman 2015; Meissner 2017), it has proven enlightening for the study Spanish colonialism in the Philippines, more specifically, to explore multiethnic power relations in Manila and the Chinese diaspora (Hsieh 2017).

Postcolonial theory offers another perspective for investigating the complex effects of colonization and colonialism, while taking into account the profound impact that these processes have had on both the colonized societies and on the colonizers. European colonialism cannot be detached from conquest, imperialism, and capitalist expansion oriented towards the search for riches, raw materials, new markets, and labor among other things. Postcolonial studies emphasize the hybrid and novel forms of culture that develop out of colonial processes, and stress the fact that, in colonial contexts, social relationships are continually changing and being reordered. Emphasis is placed on indigenous agency and on questioning the portrayal of colonizers as an homogeneous entity free of contradictions. Colonialism resulted in societies and practices characterized by asymmetrical relations of power that emphasized racial and cultural differences. Postcolonial thought also aims to deconstruct Western-imposed power structures from both past and present, to work through the complex effects of colonialism, and to decolonize the discourses and politics of the so-called peripheries (Bhabha 2004:2,5; Buscaglia 2013:71, 75-76; Dommelen 2006:111; Gosden 2001:243; Liebmann 2008:2).

Colonial contexts were spaces in which the cultural order could be questioned and redefined. This happened during the construction of social relations, the acceptance and rejection of certain practices, the redefinition or not of their meanings, and it depended on the particular context, identities, positions, and interests of the individuals and groups involved in the interaction. New practices and identities emerged as a result of negotiations in which both local agency and colonial structures had creative roles. Indigenous people were not considered passive recipients of the changes brought by the colonial regime and Europeans were not impermeable to these changes either (Buscaglia 2013:81-82).

An important concept in postcolonial theory is that of hybridity, developed by Homi Bhabha (2004), which refers to the creation of new cultural forms that emanate from the processes of interaction between colonizers and colonized. This is also a way to avoid binary oppositions because it introduces a third space in which it is possible to analyze ambiguous, contradictory and confusing patterns in the visual, textual, and material culture of the particular colonial situation. It is precisely in this hybridization process where fissures in colonial control can become visible (Buscaglia 2013:82-83).

Archaeology can offer unique insights into colonial experiences. Not only does it provide access to the material dimension of colonial encounters and daily life interactions in colonial settings, it also provides a richer view into the past than that obtained through historical documents alone. While texts tend to present only the perspective of a dominant group, archaeology provides the possibility of studying the past from the perspective of groups that are not as visible in historical records because material culture is multivocal by nature (Buscaglia 2013; Dietler 2010:20-21). Postcolonial theory is especially helpful when considering the role that material culture played in the negotiation of social relations. According to Gosden (2012:252) postcolonial archaeology should show awareness of colonial histories in terms of both their material and economic impacts and of the forms of thought which the colonial regime produced. Approaching the archaeological material in this manner makes it possible to consider the multiple influences affecting production and the symbolic meaning that different materials and products may have had for different groups.

Historical archaeology in Latin America has come a long way since the first studies were published. Although historical archaeologists have relied on American and European theoretical perspectives, and continue to do so, since the 1990s historical archaeologists in Brazil, Argentina, and Uruguay have developed their own conceptual models to study the recent past and decolonize its study (Buscaglia 2013:72-74). Efforts have also been made to devise projects grounded on postcolonial theory such as those that emphasize the subaltern as well as multivocality and community archaeology. Instead of looking at minorities as passive victims of colonization, subaltern studies re-evaluate the role minorities played in altering and resisting the dominant systems, emphasizing the active role they played in transforming the colonial order (Buscaglia 2013; Mallon 1994).

Postcolonial studies in Latin America emphasize a pluralistic approach that considers the multi-directional nature of interethnic relations as well as the processes of change that emerge from them. This perspective requires a reconsideration of the actors in the weft of colonial power relations, including colonists, indigenous people, and other ethnic groups, none of which were monolithic or static. Pluralist perspectives are necessary to avoid falling back on the binary systems (dominant colonizers/subjugated colonized) that perpetuate Eurocentric perspectives and colonial ideologies. Such perspectives permit to explore the nuances in relationships of power from the local to the global scale (Buscaglia 2013:78, 80).

Many postcolonial studies focus on resistance. But it is important to not stop at what is rejected from the dominant system but also to pay attention at the transformations that subaltern groups introduce into it. It is in daily life where the power of subaltern groups becomes more conspicuous and more invisible to the colonizer's eyes and sometimes even to those from whom it emanates (Buscaglia 2013:80). Historical archaeology projects that have focused on resistance in Mexico include studies regarding the Caste war in the Yucatán peninsula (Alexander 2004), the unconquered Lacandon in Chiapas (Palka 2005), and resistance to conquest and rebellion movements in the Maya area (R. Alexander et al. 2018), as well as research on a settlement of runaway slaves in Veracruz (Amaral 2017), and the strategic use of material culture in central Mexico (Charlton and Fournier 2010; Rodríguez-Alegría 2010; Zborover 2015b) and Oaxaca (Zborover 2015b).

Other postcolonial approaches that have been used in historical archaeology are community archaeology, in which control of a project is relinquished at least partially to the local command (Marshall 2002); and indigenous archaeologies, which are done with, for, and by indigenous people (Preucel and Cipolla 2008:131). Such approaches have been used by some archaeologists working in Mexico (Ardren 2002; Breglia 2007; Cohen and Solinis-Casparius 2017; Geurds 2006, 2007), including researchers undertaking historical archaeology projects (Konwest and King 2012; Zborover 2015b:306-309; Zimmermann et al. 2020). While efforts have been made to create community museums in some areas (Hoobler 2006), in Mexico there is still a long way to go in terms of recognizing the need to involve local stakeholder communities in archaeological projects, but more and more researchers are becoming aware of its importance and recognizing it as one of the ways in which archaeology can be decolonized.

An important part of postcolonial theory has been the development of subaltern studies (Guha and Spivak 1988; Spivak 1996:205), which focus on how the groups devoid of formal power affect dominant discourses. Indications of this subtle interventions can be found in silences, constants, contradictions, ambiguities, cracks, and inconsistencies in the official discourse (Hall 1999:192, 202). It is in these spaces where subaltern actors and practices become visible and acquire a voice. Material culture represents a vehicle through which subaltern groups can introduce variations, silently penetrate dominant structures, generate alternatives, impose limits, and subvert the existing order without an overt opposition (Buscaglia 2013:84-85). This makes archaeology an ideal discipline to explore the material expressions of subaltern communities and populations. Indeed, archaeological studies have increasingly focused on the people whose lives and cultures were disrupted by macroscale political processes like colonization, displacement, forced migration, enslavement, and economic deprivation (Voss 2015:664).

Recent archaeological studies about colonial experiences have emphasized the fact that not every colonial encounter occurred and developed in the same way, and thus, each colonial experience should be studied and contextualized in its specifically local terms (Dommelen 2002:142). Archaeological studies of colonial situations such as those by Lightfoot (2005) in California, and Dietler (2010) in Mediterranean France, have demonstrated the usefulness of multidimensional and multiscalar approaches to understanding the complexity of encounters involving diverse cultural groups. These studies emphasize the importance of analyzing colonial contexts in a long-term diachronic perspective and in performing a symmetrical analysis of the transformations in each of the groups involved, so that they are considered as both dynamic agents and products of the colonial encounter.

A long-term approach has been emphasized for the understanding of the phenomenon of colonialism in its full extent and it can also be very useful for the study of particular situations, locations, people, or systems within a colonial situation (Lightfoot 2005:234; Montón-Subías et al. 2016:4). This type of approach is both useful and necessary to study the transfer of glass technology to the Americas and its development in the colonial period. The initial technology transfer happened during the sixteenth century, but there is no archaeological evidence from that period. To get a glimpse into how this transfer might have occurred we need to rely on historical documents. However, by using a long term perspective, it is possible to evaluate the continuity or change in the choice of raw materials used through the study of archaeological glass from later in the colonial period. This can indicate the extent to which glassmakers adhered to European ways or if a local technological tradition emerged. A long term perspective is also useful to evaluate changes in the organization of production as well as on the use and perception of the material.

A multiscale approach through network analysis can also be useful in the study of colonial glass production. Although glass technology was transferred to the Americas mostly by Spanish glassmakers, its activation in New Spain relied on both traditional ecological knowledge of indigenous communities and on indigenous labor, particularly in terms of procurement of raw materials. Moreover, given that glassmakers established themselves in two major cities, the craft was certainly not conducted in isolation. For this reason, colonial glass production needs to be studied from multiple perspectives, starting with single localities, in this case Mexico City and Puebla which were the main production centers of glass in New Spain. Glass production also needs to be looked at from an indigenous perspective, because these groups were the suppliers of essential raw materials, and later in the Colonial period, became glassmakers themselves. It is also necessary to take into account the singularities of local contexts without losing sight of a comparative perspective, and to consider the heterogeneity of places, processes, actors and practices involved (Buscaglia 2013:73). Glassmakers in Puebla and Mexico City made glass articles not only for New Spain but also for other territories under Spanish rule. Consequently, glass production needs to be considered in terms of the region, the viceroyalty, and the broader Spanish empire. In addition, the glass artisans in New Spain continued being influenced by European trends through the arrival of both glassmakers and European goods in Spanish galleons.

## 3.2. Anthropology of Technology

The term technology incorporates all aspects of the process of action upon matter (Lemonnier 1992:1). It incorporates a corpus of objects, behaviors, and knowledge for creating and using products that are transmitted between generations (Schiffer and Skibo 1987:595). Technologies are generated, used, transmitted, learned, and innovated in social and cultural contexts so they are first and foremost social productions. For this reason, their study involves investigating not only matter, energy, and objects, but also processes, gestures, and human knowledge as well as how these relate to each other and to other social phenomena (Lemonnier 1992:1-2,5-6, 11; 1993:3). Technologies can therefore be analyzed as cultural choices which depend on the social, economic, and ideological context as much as they do on functional criteria (Sillar and Tite 2000:3).

The anthropological study of technology can focus on different aspects including life cycles of artifacts, technological change, organization of production, design and style, invention and innovation, technology transfer and adoption (Schiffer 2011), technological choices (Sillar and Tite 2000), identity construction and maintenance (Costin 1998), apprenticeship (O'Connor 2005, 2007; Wendrich 2012), and communities of practice (Wenger 1998), among others. Some scholars (*e.g.*, Miller 2007:2-5) advocate for a more holistic study of technology and prefer to consider them both as practice and as systems, that is, as a set of interconnections between people and objects involving processes, actions, and relationships, from the design of the object to its discard. Whatever the approach, it is important to keep in mind that technologies are usually interrelated and may share tools, techniques, and social actors, or may even be codependent (Lemonnier 1992:8; Miller 2007:240-242).

In Mexico, colonial technologies have been the focus of numerous archaeological studies and have often been combined with archaeometric studies focused on the acquisition and interpretation of scientific data from the analysis of the artifacts. A large number of them have explored colonial ceramics and pottery production (Blackman et al. 2006; Fournier et al. 2012; Fournier et al. 2017; Guerrero-Rivero et al. 2020; Heath-Stout 2019; Iñañez et al. 2013; Iñañez et al. 2010; Monroy Guzmán et al. 2005; Olin and Myers 1992; Rodríguez-Alegría et al. 2013; Rodríguez-Alegría et al. 2003; Velasquez and Salgado-Ceballos 2018). There are also studies on post-conquest obsidian procurement (Millhauser et al. 2011; Rodríguez-Alegría et al. 2013), colonial metallurgy (García Zaldúa and Hosler 2020; Hernandez et al. 2016; Polónia and García Zaldúa 2019), and an archaeomagnetic study of a colonial lime burning kiln (Hernández Álvarez et al. 2017).

Other colonial technologies that have been studied by historical archaeologists in Mexico without incorporating scientific analyses are charcoal production and mining (Fournier García 2018; Fournier García and López Aguilar 2015), obsidian tool production (Pastrana Cruz et al. 2019), and sugar production (Murrieta Flores 2008). Archaeological study of technology in Mexico has also expanded into the nineteenth and early twentieth centuries as part of industrial archaeology projects and include the processing of henequen (Herández Álvarez 2019), and wheat (Morales Moreno 2008), leather tanning (Allende Carrera 2015), production of carbonated beverages (Reynoso 2005), and industrial paper making (Moreno et al. 1997).

The physical properties of matter allow for a vast range of technical possibilities and there is also a great degree of creativity in the way people engage with it. Any manufacturing process requires the producer to make technological choices throughout the different stages of production which involve selecting from a range of possible raw materials, tools, energy sources, techniques, and the sequence in which these acts are linked together. These choices are influenced not only by the natural environment and the performance characteristics desired in the product, but also by socio-economic and cultural factors that determine which options are available according to a particular worldview (Sillar and Tite 2000:3-5).

To understand and analyze technologies, identify technical choices, and elucidate how they fit into the wider cultural context the concept of *chaîne operatoire* can be very useful. This concept refers to the operation sequencing (operation by process or steps of production), culturally derived, by which naturally occurring raw materials are selected, shaped, and transformed into usable products (Lemonnier 1992:26; Leroi-Gourhan 1993:230-233, 253-254; Schlanger 2005). Techniques are sequentially organized by means of an operating syntax that gives both fixity and flexibility to the series of operations involved (Leroi-Gourhan 1993:114).

Analyzing in detail each stage of the process makes it possible to determine variations in materials, movements, and moments representing choice (Wendrich 2013:200-201).

While the concept of *chaîne operatoire* emphasizes human-enacted action on materials to produce artifacts, other scholars consider materials themselves as active, and having a degree of "agency" in a manufacturing process. Ingold (2010:93-94), for instance, argues that action upon matter can be understood as intervening in the fields of force of materials rather than as imposing a preconceived form into inert substance. Materials have inherent properties that are not necessarily predisposed to fall into the shapes required of them or to keep them indefinitely, and matter in general is in constant flux or variation, so from this point of view materials are active and humans are merely combining them or redirecting their flow. Sennett (2008:173) provides an example of this in glass working: molten glass has a tendency to sag unless the artisan keeps turning the blowpipe; he also emphasizes the need of an artisan to develop an awareness of their body in relation to the material, which O'Connor (2005, 2007) experienced when learning how to make a glass goblet and needed to make adjustments when she was failing.

In terms of material-human engagement, the material world can forge, shape, mediate, interpolate, and even challenge and undermine social relationships. To understand fully how the material world engages in these processes it is important to investigate the specific moments of crafting, exchanging, using, and discarding objects (Meskell 2005:6-7). Ethnoarchaeological studies can provide a way to investigate these moments. As a theory and research strategy, ethnoarchaeology involves the ethnographic study of living cultures from an archaeological point of view. Through the investigation of cultural systems and contemporary materials, the researcher can obtain reference data that can help propose models, hypotheses, datasets, testable analogies, and frameworks that are useful for archaeological interpretations (David and Kramer

2001:2; Hodder 1982:38; Sinopoli 1991:71). Ethnoarchaeological studies can also provide multiple explanations when our own cultural context may only suggest a few (Fischer 2008:83), reminding us that interpretations of the past are made within the context of the researcher's social and cultural background (Iles and Childs 2014:193, 200).

Ethnoarchaeology has proved to be very useful in the study of different technologies in Mexico and has been widely applied to investigate ceramic production (Arnold 2005, 2008; Arnold 1991; Charlton and Katz 1979; Deal 1988; Foster 1960; Fournier García 2011; Fournier García 2007; Kaplan 1980; López Aguilar et al. 1988; López Varela 2005; Mondragón et al. 1997; Nahmad Molinari 2018; Shott 2018; Stark 1984; Sugiura Yamamoto and Serra 1990; Williams 2017, 2018), as well as metalworking (Iles and Childs 2014; Maldonado 2005, 2018), and lithic technology (Hayden and Nelson 1981; Rodríguez-Yc 2013; Vargas Díaz 2013). Ethnoarchaeological approaches have also been useful for the study of glass production worldwide (Castillo Cárdenas 2016; Charlesworth 1967; De Angelis et al. 2013; Fischer 2008; Kanungo 2000; Kock and Sode 1996; Sode and Kock 2001; Stern 1999; Susak Pitzer 2015); and ethnographic work on the apprenticeship of glassblowing (O'Connor 2005, 2006, 2007, 2017), has provided key insights into the learning process of the craft and the embodied experience of an artisan engaging with the material.

Another approach to the study of technologies is experimental archaeology. This approach is useful to find answers to some of the questions that emerge when studying ancient technologies that are not adequately answered through the analysis of archaeological materials and context, historical records, or other methods. Experiments can function as reference models in which all the details of a production process are known and one or more variables are investigated in a controlled manner, or they can be designed to replicate or reverse engineer a particular technology. In this way, experimental archaeology can help us better understand the relationship between the physical properties of a material, manufacturing processes, and technological choices (Albero Santacreu 2014:118-119; Morgado Rodríguez and Baena Preysler 2011:23).

In Mexico, experimental archaeology has been predominantly used to study prehispanic technologies such as lithic production (Hirth 2003; Walton 2019), ceramic raw material procurement (Stoner et al. 2014), lost-wax copper casting (Long 1964), and lime production (Russell and Dahlin 2007), but it has rarely been used to study colonial technologies. One of the only examples is a study on clay sources to investigate ceramic production in an Afromestizo neighborhood in Veracruz (Eschbach 2019).

Experimental approaches linked to the study of archaeological glass have been extensively used to explore many aspects of the glass production process including furnace construction, efficiency, and waste products (Paynter 2008; Taylor and Hill 2008), the suitability of different types of sands for glassmaking (Brems et al. 2012), the effects of firing temperature on glass (Shugar and Rehren 2002), recognizing frit as an intermediate stage in glassmaking (Paynter and Dungworth 2011b), the effects of silica processing on glass (Silvestri et al. 2006), the use of different alkali raw materials in glassmaking (Jackson and Smedley 2004; C. M. Jackson and J. W. Smedley 2008; Shortland et al. 2011; Smedley and Jackson 2006), batch measuring practices (Smedley and Jackson 2002b), and the effects of glass recycling (Scott et al. 2017) among others.

### 3.4. Integrating Approaches

This research brings together multiple lines of evidence and approaches to the study of colonial glass technology in Mexico. It follows a multidisciplinary approach to study a material that in many ways reflects colonialism and the responses to colonial encounters associated with the European expansion of the Early Modern period. Glass technology is a European introduction, but its adaptation to the New World required a full immersion into the colonial reality. Through an integrated approach intertwining archaeological materials science, and ethnoarchaeology, with historical research it is possible to investigate the transfer of this technology into the Americas and its development in Mexico. Archaeological materials science applying cutting-edge techniques to scientifically analyze an archaeological glass collection provides an effective way to explore technology transfer, adaptation, and adoption.

The above overview on different perspectives to the study of colonial situations, emphasizing postcolonial theory, and the different approaches to the study technology shows how intricate the analysis of an archaeological glass collection can be if we are to take into consideration the complexities of the colonial context in which this material culture was produced. However, bringing together archaeology, theoretical perspectives from the social sciences and/or humanities, and scientific analysis can not only be done, but is becoming more frequent and in some cases necessary to study of the human past (Martinón-Torres and Killick 2015). This divide was first brought to the fore by Snow (1961:2) at the end of the 1950s, where he noted the lack of communication between the "two cultures," that is, between the sciences and the humanities. In archaeology, this may be in part because many archaeological scientists have university positions in departments such as geology, chemistry, physics, or materials science, and people outside of the field of archaeometry might not immediately search for that kind of archaeological expertise outside of anthropology and archaeology departments (Bonneau et al. 2014:35). The divide persists until today. Some researchers have argued that there is a lack of understanding between archaeology and science and advocate for keeping strict boundaries between disciplines; other researchers, on both sides, consider either one or the other as a superior or more rigorous path to interpretation and knowledge of the past. But archaeology and science do not have to be seen as estranged camps. Today more researchers are crossing the boundaries between different specialties, more scientists and archaeologists are interacting directly, and more scholars are getting training in both archaeological methods and theory as well as in scientific analysis. Indeed, combining different approaches, methodologies, and lines of evidence can greatly enhance our ability to understand past societies, each one providing information on particular aspects of a research project (Martinón-Torres 2008:16, 33; Martinón-Torres and Killick 2015; Pollard and Bray 2007:246).

Hodder (2012), for instance, has proposed the concept of entanglement as a way to move beyond the limits of material culture and social theory in order to incorporate material science into archaeology and to take into account the physical and chemical properties of materials into social interpretations. Entanglement brings attention to the object to explore how society and things are co-entangled. It allows materiality to be embedded within the social, the historical, and the contingent (Hodder 2012:3-5, 96-98, 112, 206-208).

Pollard and Bray (2007:246-247, 255-256) consider that archaeology and science can work in equal partnership, with equal inputs and shared objectives towards the understanding of the past. But for this approach to work, mutually intelligible communication and equal respect for both fields is key; effective multidisciplinary work and fruitful collaborations both require a basic understanding of the disciplines involved.

The path towards more integration of archaeology and science has taken decades to develop and in many respects is still a work in progress. But a growing body of research that integrates science with archaeology and other disciplines that study the past and cultural heritage shows that it is, indeed, possible to integrate seemingly incompatible approaches in order to learn about the human past (Maldonado 2018; Salinas and Pradell 2020; Swan 2012). This dissertation aims to contribute to this effort by applying an integrated approach that brings together the “two cultures” to answer questions that cannot be otherwise adequately addressed. Archaeological glass and the study of the technology behind it provide ample opportunities for scientific enquiry, but as stated above, technologies are first and foremost social products. Both aspects are equally important and, together, they can tell a much more interesting story than either approach can tell on their own.

# 4. ANALYSIS OF COLONIAL MEXICAN GLASS: MATERIALS AND METHODS

## 4.1. General Methodological Approach

This research encompasses a holistic, multidisciplinary approach incorporating archaeology, ethnoarchaeology, history, and materials science principles and methods to analyze the processes of adoption and adaptation of glass production in colonial Mexico and to understand the role glass has played in the negotiation of social relationships in colonial Mexico. This approach enabled the technological exploration of colonial glass production represented in archaeological glass collections, as well as, an investigation of the social environment within which this technology developed.

In order to better understand the technology of glassmaking to interpret the archaeological glass collections and to obtain insights into the evidence of glassworking that would be expected in the archaeological record, an ethnoarchaeological research was conducted in glass workshops of Puebla and Guadalajara, Jalisco, the most important production center of traditional blown glass in the country today. Fischer (2008:6) argues that, to reconstruct technological knowledge, ethnographic observations and/or direct engagement with the material in question can be extremely useful and in some cases necessary. The observations made in the glass workshops of Guadalajara and Puebla, presented in a master's thesis (Castillo Cárdenas 2016), served to support the analysis of the archaeological glass collections as well as to better interpret the historical documents. This research also served to evaluate questions regarding change and continuity in the development of the Mexican glass tradition.

Historical research is an integral part of this project because documentary sources provide crucial primary information on the technology and its development, the glass artisans and the context of production, the distribution networks, the patterns of consumption and use, as well as clues about the symbolic value of glass in colonial Mexico. Research in Mexican and Spanish archives included the Archivo General de la Nación (AGN), the Archivo Histórico de Notarías de la Ciudad de México (AHNCM), the Archivo Histórico de la Ciudad de México (AHCM), the Archivo Histórico de la Arquidiócesis de Guadalajara (AHAG), the Archivo Histórico Municipal de Puebla (AHMP), and the Archivo General de Indias (AGI). This research provided a rich body of information about the earliest glass artisans in New Spain, the operation and management of colonial glass workshops, the possible location of glasshouses, the raw materials used to make glass, the economic value of glass compared to products made of other materials, and on technological changes towards the end of the viceregal era.

Both the ethnoarchaeological and historical research informed and guided the study of archaeological glass collections from the two main glass production centers of New Spain, Puebla and Mexico City. The study of the collections began with a qualitative study that looked at the formal characteristics of the objects and resulted in a typological proposal for Mexican glass. The methodology to put together the typology is described in the next section.

An essential part of the research into the transmission of glass technology to the Americas involves the study of raw materials for glassmaking and the compositional and microstructural characterization of archaeological glass collections from Mexico and Spain. The scientific analysis of raw materials was performed in order to facilitate the interpretation of the glass composition of Mexican glass samples, whereas the characterization of glass from Mexico and Spain was necessary to understand how the foreign technology was adapted to the resources available in New Spain and certain aspects of the manufacturing process. The sample collection, selection, and preparation, and the analytical techniques and parameters used to study raw materials and to characterize the archaeological glass are discussed later in this chapter.

4.2. Typological method

The archaeological glass was first classified in terms of manufacturing technique, form/function, color, and decoration. A formal analysis of each artifact was done to identify specific attributes that indicated the technique of manufacture, the type of object and possible temporality based on available typologies of archaeological glass (Deagan 1987; Hernández Arana 1980; Jones and Sullivan 1989; Lindsey 2016; Noël Hume 2001; Paynter and Dungworth 2011a; Willmott 2002). The color of the glass was classified based on the Pantone® formula guide. The state of conservation was also noted. In the case of vessels or containers, the different parts of each vessel, including lip, rim, neck, shoulder, body, and base were measured and described. Wall thickness was also calculated. Decorative elements and techniques including embossing, enameling, etching, and cutting were documented. A database was created in excel to record the information from each artifact. Diagnostic fragments (rims, bases, seals, etc.) were recorded individually, while body sherds of the same appearance were recorded together in groups.

The initial sorting was based on the identification of production waste and manufacturing techniques. The latter included casting, free-blowing, mold-blowing, molding, and stretching, all of which were used since ancient times, as well as techniques developed from the nineteenth century onwards, including pressed glass, machine-blowing, and many industrial techniques that are beyond the scope of this work. The techniques represented in the material of study are explained in Table 1.

Table 1. Definitions of glass production waste and manufacturing techniques

| **Manufacturing Technique** | **Definition** | **Types** |
|---|---|---|
| Glass production waste | Residual products resulting from glassworking. | • Moils (the leftover top of a blown object where it was joined to the blowing iron)<br>• Droplets, trails, threads, and lumps dropped around the furnace during glassworking<br>• Waste from the removal of inclusions<br>• Chunks of leftover glass<br>• Wasters (products that went wrong)<br>• Glass slag<br>• Cullet (crushed glass for recycling) (Henderson 1989:44-47; Paynter and Dungworth 2011a:14-20)<br>• Rods: elongated glass canes |
| Free-blown | Objects blown and shaped by a glass artisan without the aid of molds, using other techniques such as marvering to shape and swinging movements to elongate the gob of glass, as well as tools such as jacks and tweezers to shape it. | |
| Mold-blown | Objects shaped in molds. Molds can be closed or hinged, meaning they can be open and closed, and they can be composed of two or more parts; the latter leave a seam mark on the vessel at the points where the different parts of the mold meet. | • Without seam marks<br>• With seam marks (two-part mold, three-part mold) |
| Stretched or drawn | Objects or parts of artifacts that are made by stretching the glass gob and shaping without the need of blowing it. | • Objects (beads, figures)<br>• Vessel attachments (handles, stems, pedestal bases adornments) |
| Cast | Glass poured into a mold. | |
| Pressed | A technique developed in the United States between 1820 and 1825 in which glass objects are formed using a mechanical press without the need to blow them. This technique significantly reduced the time and labor required to make glass objects (Spillman 1983:8, 10). | |
| Machine-blown | A technique developed in the late-nineteenth century in which glass is poured into a mold and blown by compressed air (Phillips 1981:250-253). | |

The material was then divided in terms of form and function into different types of objects including: containers (bottles, phials, jars, ampoules, inkwells), tableware (drinking cups, bowls, dishes, stemware), attachments and accessories (handles, lids, stoppers), and thin flat glass, which was too thin to be used for windows or mirrors but had not curvature to indicate the fragment was part of a vessel. Window glass was not considered in this study. Every object was described based on their particular diagnostic attributes. The manner in which the main attributes of vessels were defined can be seen on Table 2. Additional attributes that were particular to a single specimen are described on a case by case basis. The term vessel was used to categorize any curved glass fragment (hollowware) that did not possess any diagnostic attributes. This list, as well as the typologies proposed below, should not be considered comprehensive because they are based only on the archaeological material used in this study, and a larger variety should be expected. Future studies of archaeological glass collections will allow to expand on this work.

Table 2. Definition of attributes of glass vessels.

| **Attribute** | **Definition** | **Types** |
|---|---|---|
| Lip | Defined in terms of its final treatment. | • Sheared: cut or sheared from the blown bottle with no further treatment (Fletcher 1972:54).<br>• Plain: once detached from the pontil, the lip was smoothed through fire-polishing (Ferraro and Ferraro 1966:10; Lindsey 2016:300).<br>• Ground: once detached from the pontil, the lip was evened out through grinding (Lindsey 2016:300-301).<br>• Applied: a ring of additional glass was trailed around the opening (White 1979:59). |
| Rim | Defined in terms of its angle. | • Straight: an angle of between 90° and 100°<br>• Slightly-everted: between 100° and 135°<br>• Everted: between 135° and 170°<br>• Horizontal:[22] between 170° and 180°<br>• Over-everted: beyond 180° |
| Closure or finish (jars and bottles) | Defined in terms of shape. | • String rim: a ring of glass was applied near the top of the neck, initially used for retaining the string which held the cork in place (Adams and Payne 1976:44). |

[22] Horizontal rims are sometimes referred to as "flared"(Adams and Payne 1976, 17; Fletcher 1972, 55).

| Attribute | Definition | Types |
|---|---|---|
| | | • Applied finish: Additional glass added to create the closure and shaped with tools (Lindsey 2016:303-309).<br>• Tooled finish: the rim was reheated and shaped with compression tools made specially for this purpose to give it a specific form without adding extra glass to the object (Lindsey 2016:309-310).<br>• Crown<br>• Screw: can be shallow or deep depending on the length of the spiral thread (Bender 2016:26). |
| Neck | Defined in terms of its length and shape. | • Short<br>• Long<br>• Concave<br>• Convex<br>• Straight<br>• Tapered: wider towards the bottom. |
| Shoulder | Defined in terms of shape. | • Convex: very rounded<br>• Slopping: descends on a diagonal line<br>• Horizontal |
| Body | Defined in terms of shape and cross-section. | • Globular<br>• Cylindrical<br>• Conical<br>• Circular in cross-section<br>• Oval in cross-section<br>• Square in cross-section<br>• Rectangular in cross-section<br>• Polygonal in cross-section (hexagonal, octagonal, etc.). |
| Stem | Defined in terms of length and technique. | • Short<br>• Long<br>• Collared: with a ring around the stem<br>• Blown<br>• Drawn |
| Base | Defined in terms of shape | • Kick or kick-up: an indentation at the base of a vessel. It can vary from very shallow to very high, it can be pointed or rounded, and they usually have a pontil mark.<br>• Flat |
| Pontil mark | Left when the pontil rod was detached from the base. | • Pontil mark: a jagged circle of excess glass around the outside surface of the kick.<br>• Clean pontil mark: when the excess glass was removed leaving only a thin line or groove on the surface of the kick.<br>• Full pontil mark: a thin film of glass was left that went across the base from side to side, covering the rest of the kick and making the base look shallower. |
| Foot | The base of stemware or vessels that do not rest directly on their base; defined in terms of shape. | • Ring: a projecting rim at the bottom<br>• Folded: turned under<br>• Pedestal |
| Seams | Defined in terms of their location. | • Lateral: running vertically on the sides of the body<br>• Medial: running horizontally towards the top of the body<br>• Basal: running horizontally towards the bottom of the body |

| Attribute | Definition | Types |
|---|---|---|
| Decoration | Defined in terms of technique. | • Applied: additional glass attachments applied when the glass is hot.<br>• Molded: blowing the glass on a mold that includes decorative designs<br>• Embossed: blowing the glass on a mold that includes text<br>• Sealed: applied by pressing a seal onto blobs of hot glass.<br>• Impressed: patterns impressed onto hot glass with tools such as pincers, toothed wheels, rasps, and files.<br>• Cameo: layers of glass of different colors; the outer layer is carved into a design revealing the inner layer color.<br>• Filigrana or *latticino*: decorated with fine glass threads (*vetro a fili, a retorti, a reticello*; see Chapter 2).<br>• Cut: glass sculpting using lapidary tools or wheel-cutting.<br>• Engraved: scratched designs using a diamond point.<br>• Enameled: annealed objects decorated with low-melting point glasses that are quickly reheated to fuse the enamel onto the surface.<br>• Gilded: gold powder mixed with a fixative material to paint the object and fired at a low temperature to fix it.<br>• Cold-gilded: gold leaf applied with a semi-permanent fixative without subsequent firing. It is easily rubbed off.<br>• Etched: contrasting shinny/matt patterns created through controlled-exposure of the object to acid. It became widely used in the 19th century.<br>• Sand-blasted: the object is blasted with a high-pressure sand gun; designs can be created by protecting certain areas (Klein and Lloyd 1984:272-274; Paynter and Dungworth 2011a:36-38; Phillips 1981:268-270). |
| Attachments and accessories | Defined in terms of shape and use. | • Handles<br>• Seals<br>• Lids<br>• Stoppers |

## 4.3. Scientific Methods

The archaeological glass samples and the raw materials from Mexico, mainly the alkali-rich plant and mineral resources, were analyzed using a multi-scale and multi-analytical approach based on hand-held non-destructive technology and through the analysis of selected microsamples. Characterization techniques included: fiber optics reflectance spectroscopy (FORS), X-ray diffraction (XRD), scanning electron microscopy coupled with energy dispersive spectroscopy (EDS) and electron probe microanalysis (EPMA) equipped with wavelength dispersive detectors (WDS), and laser ablation inductively coupled plasma mass spectrometry

(LA-ICP/MS). Preliminary examination of the samples was performed by optical and digital microscopy (OM and DM).

### 4.3.1. Fiber Optics Reflectance Spectroscopy (FORS)

Fiber optics reflectance spectroscopy (FORS) is a field-deployable non-invasive technique used to collect reflectance spectra of materials covering a range between 350 and 2500 nm, which includes the ultraviolet (UV), visible (Vis), near (NIR) and shortwave infrared (SWIR) part of the electromagnetic spectrum. Reflectance spectroscopy is based on the principle of selective light absorption and examines the spectral behavior of a material to light. The reflectance spectrum is obtained by illuminating the area of interest of an object with a broad-band light source, producing a spectral profile that provides a measure of intensity vs. wavelength from the diffusely scattered light, normalized to a white calibration standard (Beeby et al. 2018:142; Cavaleri et al. 2013:46). The light that is not reflected is absorbed or transmitted depending on the chemical composition of the material and its thickness. This technique is sensitive to electronic transitions in or between specific elements and overtones of fundamental modes, and combination bands of molecular groups (Cosentino 2014:54). FORS allows to characterize both organic and inorganic materials. In the realm of cultural heritage, it has been widely used to identify pigments, paint binders, surface coatings, and dyes (e.g., Delaney et al. 2014; Kakoulli et al. 2017; Maynez-Rojas et al. 2017), and recently to study the deterioration of historical glass (Zaleski et al. 2020).

4.3.2. X-ray Diffraction (XRD)

X-ray diffraction (XRD) is a useful technique to analyze materials with a crystalline structure, that is, materials in which the atoms are arranged in a repeating or periodic array over large atomic distances (Callister 2007:39). In XRD, monochromatic X-rays are scattered by the atoms of the lattice and a diffraction pattern containing information about the arrangement of these atoms is generated. Crystals are composed of lattices organized in a regular pattern and each crystal species has a characteristic size and spacing in its structure. For this reason, when radiation interacts with the crystal(s) in a material, it produces an X-ray pattern characteristic of the structure of the crystal. The resulting pattern can then be compared with a database of known crystal d-spacings[23] in order to identify the analyzed phase. This technique is the only way to differentiate crystal species that share the same chemical composition such as quartz, tridymite, and cristobalite, each of which forms at a different temperature (573 ±5ºC, c. 867ºC, and 1250ºC respectively) and represents a different form of silica ($SiO_2$) (Henderson 2000:10-11).

4.3.3. Scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy (EDS)

Scanning electron microscopy (SEM), coupled with energy dispersive X-ray spectroscopy (EDS) has been extensively used in the field of cultural heritage and conservation for the characterization of a large variety of artifacts and materials. The SEM uses a beam of electrons, allowing the examination of objects at very high magnifications. SEM imaging can be done through the detection of secondary and back scattered electrons. Secondary electrons provide information on the topography while back scattered electrons produce an image based

[23] Distance between planes of atoms.

compositional contrast. EDS enables spatially resolved elemental characterization and mapping through the detection and measurement of characteristic X-rays. In this way, SEM-EDS permits the combined study of high resolution imaging and elemental composition analysis and mapping, and is particularly useful for the study of heterogeneous specimens (Frahm 2014:6487-6488; Henderson 2000:18; Reed 2005:45, 53, 78; Schreiner and Melcher 2018:1).

SEM-EDS is a well-established non-destructive technique for the analysis of the microstructure and general composition of vitreous artifacts. The high magnification that can be achieved with SEM is useful for the characterization of the microstructure of glass and for the identification of very small particles such as coloring agents or defects (*e.g.,* unmelted ingredients), while EDS is well-adapted for the detection of the major and minor constituents of glass (present in amounts > ~0.1wt%). However, this technique is not suitable for the detection of elements present at trace levels because of the very low penetration depth of electrons (Janssens 2013:140; Schreiner et al. 2007:742).

### 4.3.4. Electron probe microanalysis (EPMA)

An electron probe microanalyzer outfitted with several wavelength dispersive spectrometers (WDS) has a higher resolution and is more precise than EDS because it differentiates characteristic X-rays by wavelength instead of energy. With SEM-EPMA/WDS it is possible to measure elements present at lower concentrations (~ 0.01%) allowing for better quantitative analysis (Frahm 2014:6489; Henderson 2000:17; Janssens 2013:96).

4.3.5. Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS)

Quantitative analysis of elements present at trace levels, down to a few parts per million (ppm) depending on the element, is usually achieved with LA-ICP-MS. This technique permits single spot analysis with minimal invasiveness on the sample (virtually non-destructively) and permits the quantification of all the elements in the periodic table except oxygen (O) and nitrogen (N),[24] making it the technique *par excellence* to quantify trace and rare earth elements (REEs) in glass. The technique uses a high-energy laser to ablate or vaporize a small area of the sample, usually a few tenths of micrometers in diameter and less than 30 microns deep, which is transported by a carrier gas (argon or helium) into an ICP-MS torch where an argon gas plasma ionizes the vaporized sample. The resulting ions then pass to a mass-spectrometer where they are separated according to mass/charge ratio and a detector records the atomic mass range (Speakman and Neff 2005:2, 4; Tennent and van Elteren 2007:16).

4.4. Sampling and Analysis of the Alkali-rich Raw Materials

Informed by the historical research and in order to better understand the composition of Mexican glass, two fluxes used in colonial Mexico: plant ash and *tequesquite* were analyzed. To explore the possible sources for plant ash used by colonial glassmakers, samples were collected from the halophytic plants growing around the two lagoons mentioned in historical sources: Cuitzeo (Michoacán) and Texcoco (Estado de México), as well as from two other potential locations: the lagoon of Totolcingo (Puebla/Tlaxcala), and the lagoon of Sayula (Jalisco). Similarly, samples of salt efflorescence or *tequesquite* possibly used in colonial glassmaking, were collected around the aforementioned lagoons as well as from the lagoon of San Marcos

[24] Tennent and van Elteren (2007: 16) also include hydrogen (H), carbon (C), fluorine (F) and the noble gases as exceptions.

(Jalisco), located 9 km north of the Sayula lagoon. The location of the sample collection sites can be seen in Chapter 8. Details on the collection and processing of the samples collected are described below, while the results and discussion of the analyses are discussed in Chapter 8.

4.4.1. Collection, processing, and sample preparation

Two species of endemic halophytic plants were collected: *Suaeda edulis* and *Suaeda pulvinata*,[25] both of which grow in the places mentioned in historical documents. Samples from the lagoons of Texcoco and Totolcingo were collected in the winter of 2018 (dry season). Additional samples were collected in the summer of 2018 (rainy season) from the lagoons of Cuitzeo, Sayula, Texcoco, and Totolcingo. Each sample was dried under the sun for two weeks, burnt at 300º C, and ground into a fine powder. These ashes were further heated at 700º C for five hours so that the carbon was consumed.

Samples of *tequesquite* and of salt efflorescence were taken at the same locations where halophytic plants were collected with the addition of the lagoon of San Marcos. A total of nine samples, named with the initials of the sites of collection, were analyzed. All samples were collected during the dry season (winter 2018). Most of the samples represent the salts that naturally effloresce from the dry lakebed in dry season, so most of the samples are not pure and include a soil fraction. However, it was possible to obtain a sample of *tequesquite* as it was being collected at the edge of the lagoon of Totolcingo in Santa María Tequexquitla, Tlaxcala.[26] Additionally, *tequesquite* was bought in the market of San Juan in Mexico City. All of the

[25] The selection of these two species was done after consulting botanist Hilda Flores Olvera, from Instituto de Biología-UNAM, a specialist on *Amaranthaceae*, *Chenopodiaceae*, and *Nyctaginaceae* who has studied halophytic plants from central Mexico. Additional details on this particular selection and on other possible species used can be found in Chapters 6 and 8.

[26] Details on the collection of *tequesquite* in Santa María Tequexquitla are discussed in Chapters 6 and 8.

samples were ground into a fine powder and no further sample preparation was performed on the samples, except for their analysis with SEM-EDS for which the samples were pressed into pellets without the addition of any binder. Standards of known composition (andesite) were used to check the accuracy and precision of the analyses.

4.4.2. Characterization of Raw Materials

The characterization of both plant ash and *tequesquite* samples was achieved by FORS, XRD, and SEM-EDS. An ASD Inc. Fieldspec3® fiber-optic spectroradiometer (Malvern Instruments), which has a high spectral resolution (3 nm @ 700 nm and 10 nm @ 1400/ 2100 nm) and covers a spectral range from 350 to 2500 nm, was used to identify the minerals present in the *tequesquite* and plant ash samples. XRD was used to confirm the identity of alkali-rich compounds present in the fluxing agents used in New Spain that could potentially interact with silica and their ratios in relation to other components, such as sodium carbonate and sodium chloride in plant ashes (Henderson 2013:26). The analysis was performed using an X'Pert Pro PANalytical X-ray Powder Diffractometer at the Molecular Instrumentation Center of the Chemistry and Biochemistry Department of the University of California, Los Angeles. The instrument is equipped with a Cu-K$\alpha$ source and was operated with an accelerating voltage of 45 kV and a current of 40 mA, with a 5 – 100° exploration range and a 0.0167 step size with a time per step of 10 s for a total time of seven minutes. SEM-EDS analyses of the *tequesquite* and plant ashes were conducted in the Molecular and Nano Archaeology (MNA) Laboratory at University of California, Los Angeles using a FEI NOVA™ NanoSEM 230 scanning electron microscope with a field emission gun operated in high pressure low vacuum mode using a gaseous analytical detector (GAD) coupled with an EDS; BSE micrographs were obtained at an accelerating voltage of 15 kV and a current of 40 Pa.

4.5. Scientific Analysis of Archaeological Glass Collections

Using a multiscale and multi-analytical approach it was possible to investigate the composition (through the identification of major, minor, and trace elements) and the microstructure of the glass, with the objective of understanding raw material selection, technological variability, and local adaptations. The identification of major, minor, and trace elements is important to determine the raw materials used to make glass, while differences in trace elements and rare earth elements (REEs) may represent varying raw material sources and are thus crucial to determine provenance. REEs such as lanthanum (La) and neodymium (Nd), for instance, will vary in coastal and inland sand (Henderson 2013:309-310).

The archaeological material was analyzed using combined optical, electron, and spectroscopic techniques including: optical microscopy (OM), SEM-EDS, SEM coupled with an electron microprobe analyzer (EPMA) and wavelength dispersive spectrometers (WDS), and laser ablation inductively coupled plasma mass spectrometry (LA-ICP/MS). These techniques are minimally-invasive (sampling is required), and non-destructive (the sample is not consumed and can be reused for future analysis). The results obtained from the Mexican collections were then compared to those of Catalonia as well as with published compositional data from other regions in order to distinguish imported products from those locally made. To this date, there are no published technical studies on the composition of Mexican archaeological glass nor from Catalan glass. The scientific analyses performed as part of this research will be among the pioneering studies in compositional glass in Mexico and Catalonia.

### 4.5.1. Sample Selection and Preparation

Minute samples (< 2mm$^3$) were taken from selected artifacts and glass sherds for microanalysis. A total of 105 artifacts were sampled from the collections of Mexico City, 27 from Puebla, and 72 from Catalonia. Complete objects were not sampled. Glass surfaces are often altered or weathered after burial, which significantly alters the composition (Henderson 1989:33), so the samples were first analyzed under high magnifications using optical microscopy to avoid weathered glass. Microsamples were mounted in epoxy resin 1-inch rounds that were subsequently ground to expose the glass, polished, and carbon-coated. Standards of known composition including NIST SRM 610, 612, and 614, as well as Corning Archaeological Reference Glasses A, B, C, and D were used to check the accuracy and precision of the analyses. NIST SRM 610, 612, and 614 standard glasses have nominal concentration of 500 ppm, 50 ppm, and 1 ppm for trace elements respectively. The Corning Archaeological Reference Glasses were designed to approximate the major glass types in antiquity. Corning A and B are soda-lime silicate glasses, Corning C is a high-lead, high barium glass, and Corning D is a potash-lime silicate glass (Adlington 2017:2).

### 4.5.2. Characterization of Archaeological Glass Samples

The analyses of the archaeological samples were conducted in four stages, each one providing information at higher magnification and lower elemental concentration levels. The first stage involved taking optical microscopic images of each sample using a Keyence VHX-1000 digital microscope and a Nikon optical microscope at 50 – 200 x magnification to document their size and color, and to map any surface defects or corrosion layers present.

The second stage included the SEM-EDS analyses in order to record the microstructure, topography, and heterogeneity of the samples and to obtain information regarding the basic composition of the glass. The SEM-EDS analyses were conducted in the Molecular and Nano Archaeology (MNA) Laboratory at University of California, Los Angeles using two instruments: a FEI NOVA™ NanoSEM 230 scanning electron microscope with a field emission gun operated in high pressure low vacuum mode using a gaseous analytical detector (GAD) coupled with an EDS; and a Phenom G-2 SEM-EDS with a backscattered detector (BSE). BSE micrographs were obtained at an accelerating voltage of 15 kV and 20 kV and current of 50 Pa. The information obtained at this stage is useful to have a general idea of the types of glasses the samples represent, but it does not provide the accuracy needed for elemental quantification. However, this step is necessary in order to define the elements to be probed in the subsequent step. Due to time constrains, SEM-EDS analyses were not performed in the samples of Spanish glass.

The third stage was the analysis of the samples through SEM-EPMA/WDS which allowed for the quantification of major and minor elements in the glass samples and provided the calibration for the subsequent LA-ICP/MS measurements. The analysis was done using two instruments: a JXA 8200 SuperProbe electron microprobe analyzer (EPMA) equipped with five wavelength dispersive spectrometers (WDS) in the Electron Probe Lab of the Department of Earth, Planetary and Space Science of the University of California, Los Angeles, which was used to analyze the glass samples from Mexico; and a JEOL JXA-8230 microprobe analyzer equipped with five WDS spectrometers at the Centres Científics i Tecnològics Universitat de Barcelona (CCiTUB), which was used to analyze the Spanish glass samples.

The analysis of the Mexican glass samples was done at an accelerating voltage of 15 kV with a current of 15 nA. The probe diameter was 10 μm. Elements analyzed included sodium

(Na), magnesium (Mg), aluminum (Al), silicon (Si), chlorine (Cl), potassium (K), calcium (Ca), titanium (Ti), manganese (Mn), and iron (Fe). Peak positions were calibrated on corresponding standard materials. Na and K were first analyzed on each sample in order to minimize its loss due to electron irradiation. Three spots on un-corroded areas of each sample were analyzed and averaged.

The analysis of the Spanish glass samples was done at an accelerating voltage of 20 kV with a current of 6 nA with a defocused beam. The probe diameter was 10 μm. Given that the SEM-EDS analysis could not be done on the Spanish samples, more elements were analyzed including sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), sulfur (S), chlorine (Cl), potassium (K), calcium (Ca), titanium (Ti), manganese (Mn), iron (Fe), cobalt (Co), copper (Cu), zinc (Zn), strontium (Sr), antimony (Sb), and lead (Pb). Peak positions were calibrated on corresponding standard materials. Na and K were first analyzed on each sample in order to minimize its loss due to electron irradiation. Three spots on un-corroded areas of each sample were analyzed and averaged.

The fourth and last stage was the LA-ICP/MS analysis which was done in order to quantify the trace elements and REEs present in the samples. The analysis was performed using a laser ablation-inductively coupled plasma-mass spectrometer (LA-ICP-MS) in the Interdisciplinary Center for Plasma Mass Spectrometry at the University of California, Davis. An Agilent 8900 ICP-MS instrument equipped with a New Wave UP-213 laser ablation system was used. A single quad was used. Samples were ablated with laser power of 100% at 10 Hz under argon atmosphere. Spot mode with a spot size of 80 μm in diameter was used. The ablated material was transported to the plasma using helium at a 0.75 L/min gas flow rate. Laser warm up time was set to be 15 s with dwell time of 40 s and a 45 s washout delay. Calibration, drift correction, and interpretation of signals were performed using the MassHunter 4.3 Workstation Software for 8900 ICP-QQQ, G7201C, Version C.01.03, Build 505.23, Patch 4 with Si as internal standard element. Glass standard NIST SRM 610 was used for calibration. Glass standards NIST SRM 612 and 614, as well as Corning Archaeological Reference Glasses A, B, C, and D were used to cross check calibration results. Three spots from each glass sample were measured and averaged. During the sample analysis phase, all the standards were measured every time a new mount was introduced for drift correction purpose.

# 5. GLASSY MATERIALS IN PREHISPANIC MESOAMERICA

Of the three pyro-technologies developed in antiquity, people in Mesoamerica were familiar with two: ceramic and metallurgy, but the technology to make glass, the third one, was not developed in the Americas. While metallurgy requires high-temperatures, it does not necessarily represent a driving force behind the invention of glass technology (Henderson 2013:7), and the rich and sophisticated ceramic repertoire produced in Mesoamerica covered all the needs for everyday life in Prehispanic times. Although artificial glass was unknown in Mesoamerica, a strong technological tradition existed around the natural glass known as obsidian, as well as other materials with a glassy appearance such as rock crystal, alabaster or *tecali* stone, as well as gemstones like amethyst, certain types of jade and opal, emerald, and amber.[27] The Franciscan friar, Bernardino de Sahagún (1577, 1988) described some of these materials in Book 11 of his sixteenth century ethnographic manuscript known as the Florentine Codex. In relation to obsidian, Sahagún (1577:XI, 360-361; 1988:791) mentioned a black stone called *itztetl*, from which blades, known as *itztli*, were extracted. He described it as being very black, smooth, transparent, and resplendent. The crystal of the land was called *tehuilotl* and it could be found in mines and mountains together with lilac amethysts or *tlapalteuilotl*[28] (Sahagún 1577:XI, 358v; 1988:790). By crystal Sahagún probably meant rock crystal, a variety of quartz which was considered a precious stone in Mesoamerica. Among the Maya, for instance, the word

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[27] It should be noted that of the materials mentioned only obsidian is a glass; rock crystal, alabaster, amethyst, emerald, and jade are minerals, while amber is a fossilized resin.

[28] The Spanish text does not include a particular name in Nahuatl for amethyst, but in the Nahuatl text it states: "… ce qui iztac, cequi aiopaltic, camopaltic mitoa, motocaiotia tlapalteuilotl," which can be translated as: …some are white, some are water purple [lilac], purple, it can also be called tlapalteuilotl [multicolored crystal] (Sahagún 1577: XI, 358v; author's translation).

*p'uk* can mean both crystal or precious stone (Brady and Prufer 1999:132). The term green stone was applied generically to different kinds of green minerals, but those of better quality were known as *chalchihuitl* and were considered precious. *Chalchihuitl* were distinguished from emeralds, known as *quetzalitztli*, which were very green, unblemished, and transparent (Sahagún 1577:XI, 357). The friar also mentioned different kinds of amber or *apozonalli*, described as a stone that resembles water drops that shine yellow under the sunlight; and *tlapalteoxiuitl*, a fine red stone that he identified as the ruby of the land (Sahagún 1577:XI, 358-359), but most probably is a type of red opal known today as fire opal (Cruz-Ocampo et al. 2007:10-12). He also included turquoise of varying qualities, the best one called *teuxiuitl;* opal or *huitzitziltetl*, described as white and transparent but under the light it shines in many colors; and alabaster or i*ztacchalchihuitl* among many other stones (Sahagún 1577:XI, 357-358, 360, 363; 1988:789-791).

For millennia, these materials had been transformed, through knapping, chiseling, grinding, and polishing, into a wide array of artifacts; these included tools, weapons, ritual objects, articles of personal adornment, and high-status objects (Pastrana and Athie 2014:75,78). Many of these materials were also linked to social or political status, involved in ritual practices, considered to have medical properties, and some had cosmological associations or were directly related to certain deities. Obsidian in particular, was a strategic multifunctional material used in great quantities by people all over Mesoamerica. It was the primary material used for the making of cutting tools and weapons and it had been part of long distance trade networks for centuries (Pastrana and Carballo 2016:329).

In the study of the processes behind the transfer of glass technology to the Americas, it is important to understand the different ways in which artificial glass could have been perceived by the native population. This is necessary to understand to what degree was glass locally adopted as well as how the material might have been used in the negotiation of colonial social relationships. For these purposes we need to first understand how obsidian and other materials with a glassy appearance were perceived and used in Mesoamerica. These materials share with man-made glass certain characteristics that were sought after and valued in Mesoamerica, such as resplendence, shimmer, translucency, smoothness, coldness, sharpness, and iridescence (Urcid 2010:127). What follows is an overview of the various uses, symbolisms, and associations that obsidian and glass-like materials had in Mesoamerican cultures with a focus on the Postclassic period, the era preceding the arrival of the Europeans to the New World.

### 5.1. Significant Material Properties

Obsidian is a volcanic glass formed when incandescent lava with a high content of silica and aluminum cools quickly. It is classified as a glass because it has an amorphous molecular structure (Corona Esquivel 1994:13,16; Pastrana 2006:50). People in Mesoamerica took advantage of obsidian's unique physical properties. It is strong, sharp, durable,[29] and being an amorphous material, it has conchoidal fracture which is both predictable and clean allowing it to be knapped and pressure-flaked. These characteristics made it an ideal material for the manufacture of a variety of implements (Figure 20) including knives, scrapers, prismatic blades, perforators, and gravers necessary for basic productive activities and craft production (Pastrana and Athie 2014:78; Pastrana and Carballo 2016:229, 333; Saunders 2001:222). Other materials such as rock crystal or alabaster lack the predictable fracture characteristic of obsidian so the technique of knapping does not work as well as it does in obsidian; however, such materials were

[29] While obsidian edges dull very rapidly, these can be reworked to sharpen them, extending the useful life of the artifact.

worked into artifacts by chiseling, grinding, and polishing, which are techniques pertaining to a craft known as lapidary (Charlton and Pastrana 2016:343). It should be noted that amber also has conchoidal fracture, but it was not used to make tools (Lowe 2004a:19).

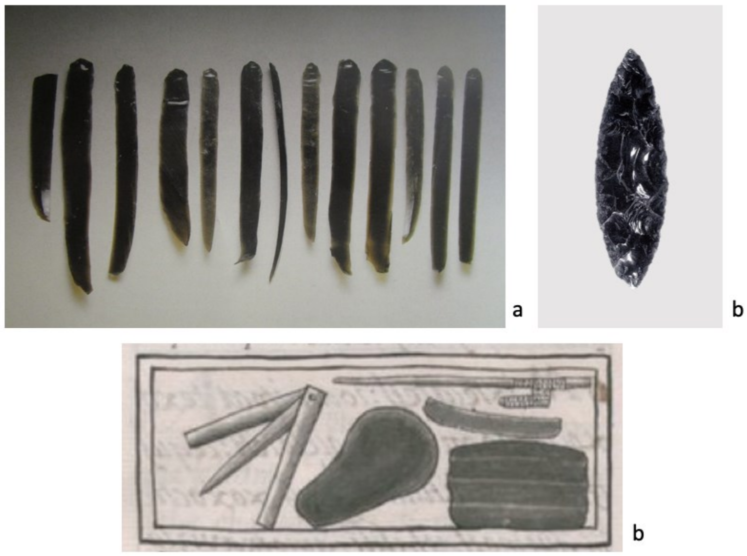

Figure 20. Examples of obsidian tools: a) prismatic blades, Teotihuacan, 600-900 CE, Museo Nacional de Antropología (Serra Puche and Solís Olguín 1994:46; photo: Michel Zabé); b) knife, Aztec, 1200-1500 CE (Metropolitan Museum of Art online catalog)[30]; c) Representations of obsidian tools in the Florentine Codex (Sahagún 1577:360v).

Obsidian and other materials of glassy appearance have a range of optical qualities such as reflection, shimmer, and iridescence, as well as different colors and degrees of transparency and translucency. Refraction does not seem to have been a property used in Mesoamerica, considering that spherical polished objects other than small beads are rare (Lunazzi 2016:126). The optical qualities of obsidian and other glassy materials that were meaningful in Mesoamerica are discussed below.

Color was of paramount importance given that different colors had different meanings and associations. While most obsidian is black, the presence of impurities, crystals, and other

[30]https://www.metmuseum.org/art/collection/search/307737?searchField=All&sortBy=Relevance&ft=aztec+obsidian&offset=0&rpp=20&pos=8.

elements can result in an array of colors including grey, green, brown, red, and golden (Figure 21a and b) (Corona Esquivel 1994:13). Green materials like jade, quetzal feathers, and green obsidian were considered very valuable by many Mesoamerican cultures (Pastrana and Athie 2014:84). In the Maya area, green obsidian was associated with the center of the world, which conveyed it with ideological and social significance (Aoyama 2014:152). In Oaxaca and Michoacán, green obsidian was related with the greening of the land, which depended on rain, and it may have also expressed notions of fertility and rejuvenation (Darras 1998:29; Levine 2014a:176-181). The Mexica greatly valued green obsidian and reserved it for the fabrication of prismatic blades, which were used for ritual bloodletting practices; other varieties of obsidian were used to make bifacial instruments (Parry 2014:295; Pastrana and Athie 2014:84). Pastrana (2006:53) argues that among the Toltecs, the eccentrics[31] made of green obsidian represented drops of water, but when eccentrics were covered in red pigment, they represented drops of blood. For both Mexicas and Mayans, obsidian and chert were conceived as inseparable because they are often found in association with one another, and their opposing colors were emphasized. Obsidian was associated with the color black, cold temperature, and the underworld. Chert, lighter in color, was considered warm and a metaphor of celestial divinity (Darras 2014:46).

[31] Obsidian eccentrics are objects shaped by knapping into anthropomorphic, zoomorphic, and other symbolic forms. Some of the most common shapes include silhouettes of humans and serpents (**Error! Reference source not found.**a), as well as trilobals, which are shaped like a letter "C" or a number "3" (**Error! Reference source not found.**b) (Parry 2014: 298).


Figure 21. Obsidian eccentrics of various colors: a) Teotihuacan, 200-205 CE, Zona de Monumentos Arqueológicos de Teotihuacan; b) Xaltocan, Museo de Xaltocan (photos: Karime Castillo).

Amber's yellow color was related to gold and the sun, and it also symbolized the color of earth's new skin before the rainy season (Carmona Macias 1997:28). There are many varieties of amber in southern Mexico (Figure 22), and the descriptions in the Florentine Codex show that different qualities of amber were recognized depending on its color: *apozonalli* or yellow amber, which seemed to have a spark of fire inside them; *quetzal apozonalli*, which were those that had a green ting mixed with the yellow color; and *yztac apozonalli*, which were whitish yellow and not very transparent, so they were considered of lesser quality (Sahagún 1577:XI, 359). Alabaster's white color was also significant. White was associated with the north, which was the direction where ancestors were located. White was also associated with rain, which was believed to originate in caves and came with notions of rebirth, renewal, and fertility (Luke 2008:311).

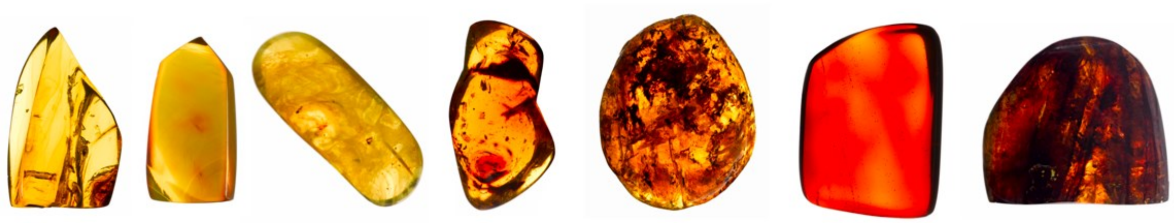

Figure 22. Different varieties of amber from Chiapas (National Museums Scotland online catalogue).

Reflective qualities were also considered important and this is evident in the use of obsidian to make mirrors. Excluding mirrors made with metals, pyrite, and other iron ores, most mirrors were made of obsidian (Figure 23), but some made of jade have also been reported (Taube 2004:141, 289). The reflective surface was generally achieved by grinding and polishing a piece of obsidian previously prepared through bifacial reduction (Pastrana and Carballo 2016:338); however, there are also reports of obsidian mirrors from western Mexico made by direct percussion with a single blow from prepared cores, with no need of polishing (Long 1966:40, 228-230; Schöndube and Galván 1978:153-154; Taube 2016:290). The Mayans employed obsidian mirrors for divination (Parry 2014:280). Using mirrors as part of the ritual practice of scrying was done in many parts of Mesoamerica (Taube 2016:286). Given their capacity for projecting an inverse reflection of the spectator's reality, mirrors were used as divinatory devices or magical portals to communicate with other realms or dimensions. In this way, mirrors could serve as passageways for supernatural beings that allowed the initiated user – usually a ruler, shaman, or priest – to communicate with ancestors or with the gods (Gallaga 2016:4; Taube 2016:304). Mirrors could also have been used to reflect sunlight as a reflection of the divine, as self-reflective devices, and for more utilitarian purposes such as making fire and communicating by means of sunlight (Lunazzi 2016:129-130).

Figure 23. Obsidian Mirror, Mexico, before 16th century (Metropolitan Museum of Art online catalogue).[32]

In addition, lapidaries were able to bring out other sought-after qualities in glassy materials such as shine and glimmer through intense polishing. Sahagún (1577:IX, 363) mentions that lapidaries working with rock crystal, amethyst, emerald, and green stone polished the artifacts carefully so that they would be brilliant, sparkling, and shiny. The importance that these qualities had is evident in ritual, ceremonial, and funerary objects that were polished to perfection. Masks, figurines, small sculptures, scepters, ceremonial receptacles, plaques, and articles of personal adornment represent some examples (Figure 24). Shiny mosaic pieces were also made to decorate masks and other artifacts (Charlton and Pastrana 2016:343-344).

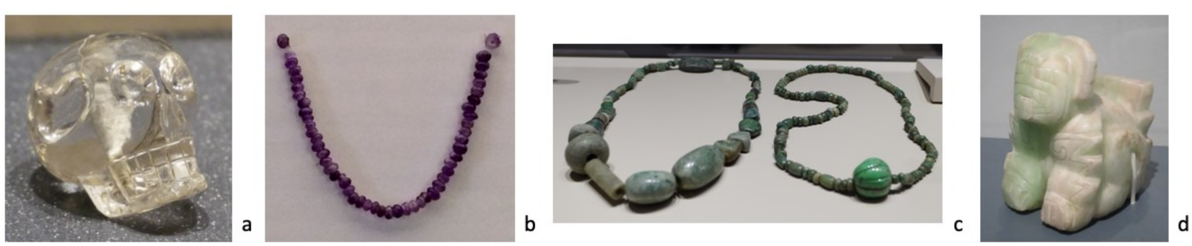


Figure 24. Polished lapidary objects: a) rock crystal skull, Mixtec, Museo Nacional de Antropología; b) amethyst beads, Museo Amparo; c) jade beads, Mayan, 500 BCE-250 CE, Museo Nacional de Antropología; d) Tecali stone feline effigy, 400-500 CE, Museo Nacional de Antropología (photos: Karime Castillo).

[32]https://www.metmuseum.org/art/collection/search/317411?searchField=All&sortBy=Relevance&ft=obsidian+mirror&offset=0&rpp=20&pos=2.

Transparency and translucency were other characteristics greatly appreciated by Mesoamerican cultures. Transparency, a characteristic shared by quetzal feathers, obsidian, rock crystal, and some varieties of jade, was associated with concepts of purity (Carmona Macias 1997:28; Pastrana and Athie 2014:84). For the Tarascan or Purepecha, translucent obsidian, even if black, was associated with a light color and the celestial world, while translucent green was related to water, life, rebirth, vegetal abundance, and the aquatic underworld (Darras 2014:68). The translucent and transparent qualities of materials like rock crystal and alabaster were highlighted in certain objects. Examples include Mixtec rock crystal zoomorphic figurines (Figure 25a) (Serra Puche 1994:206-209); an alabaster mask from Templo Mayor (Figure 25b); alabaster vessels from Isla de Sacrificios (Figure 25c) and the Mixtec region, and a rock-crystal drinking cup found as part of the offerings in Tomb 7 of Monte Albán (Figure 25d) (Serra Puche 1994:199).

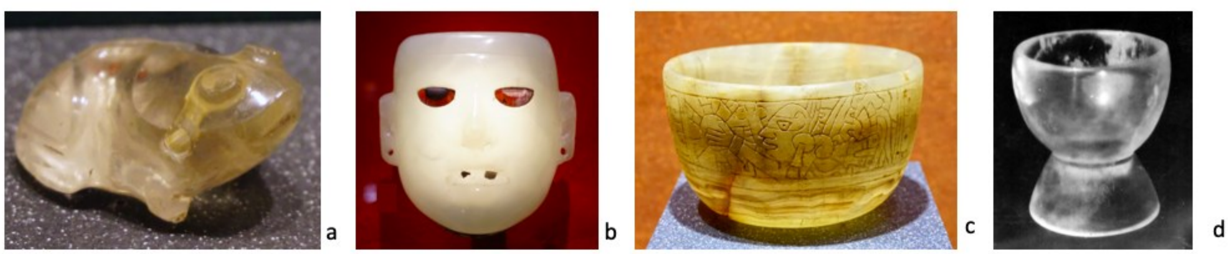


Figure 25. Lapiday objects with translucent and transparent qualities: a) frog figurine, Mixtec, Museo Nacional de Antropología; b) alabaster mask, Museo Templo Mayor; c) alabaster bowl, Isla de Sacrificios, Museo Nacional de Antropología (photos: Karime Castillo); d) rock-crystal cup, Monte Albán, Museo de las Culturas de Oaxaca (Mediateca INAH).[33]

Sound may have represented another relevant characteristic, particularly in the case of obsidian. The clinking sound made by obsidian when it fractures allowed the artisan to determine the usefulness of the material, which had to be as pure as possible. Any impurity would have

[33] https://mediateca.inah.gob.mx/islandora_74/islandora/object/fotografia%3A275709.

produced faulty results when attempting to work obsidian into artifacts. In addition to determining its workability, obsidian's distinctive sonorous qualities had other meanings and uses. In obsidian sources located in areas of pluvial erosion, like Otumba in Estado de México and Sierra de las Navajas in Hidalgo, seasonal waters expose obsidian flows, which under the rain produce a particular sound similar to thunder. The sound made by obsidian during hailstorms was thought to be related to the punishment of the gods. It is also worth considering that obsidian attached to clothing or worn as pendants would have rattled as the wearer moved or danced, which may have been desirable in certain kinds of rituals (Parry 2014:300; Pastrana and Athie 2014:89-91). An example of this kind of clothing attachments may be represented by a group of small pointed obsidian blades with tiny notches near the platform that were found in some of the burials in the Moon Pyramid of Teotihuacan (Parry 2014:296).

5.2. Cosmological and Divine Associations

In the Mesoamerican worldview, spiritual essence and animated cosmic forces permeated the natural realm. The universe was ruled by powerful gods who continuously regenerated the physical world, which was regarded as a living entity. Humans repaid them through ritual bloodletting acts that were calendrically determined to ensure the maintenance of the cosmogonic order. The physical landscape figured prominently in mythic narratives, with prominent features such as mountains or volcanoes often becoming sacred spaces. In this context, certain types of matter that occurred or were generated in such sacred spaces, were perceived as having special qualities and powers bestowed upon them by their source, allowing them to function as bridges between the physical and the supernatural world (Saunders 2001:220; 2004:123, 129-130).

The most important obsidian deposits in Mesoamerica are found in mountainous volcanic regions which are often related with myths of primordial origins and powerful deities (Levine 2014b:19). Any material extracted from a sacred landscape feature, retained parts of the mythological significance attributed to its source (Saunders 2004:129). Such imbued power may be exemplified by the inlaid disks of obsidian, jade, or other semiprecious stone that were set in a cavity in the chest of many Aztec and Toltec sculptures (Figure 26). These disks were believed to confer the figure with power and life, functioning as a heart (García Granados 2012:56; Weismann 1950:13).

Figure 26. Aztec sculptures with a cavity on the chest where inlays were placed, Museo Nacional de Antropología (photo: Xuan Che,[34] detail).

Obsidian quarries often show evidence of religious practices connected to both surface exploitation and subsurface mining. In many cultures, minerals were considered animate beings that grew in the matrix of the earth and shared its sacred qualities. In this context, mining meant a disturbance of earth's entrails and the order of the underworld (Eliade 1983:4). Obsidian

[34] https://commons.wikimedia.org/wiki/File:Aztec_gods-_Coatlique_(left)_and_Xiuhtecuhtli-Huitzilopochtli_(right).jpg

exploitation probably evoked similar ideas and this is supported by the presence of incense burners that are sometimes found in these activity areas. According to Pastrana and Athie (2014:80), the process of mining appears to have been guided by religious concepts that determined the schedule and order of activities to be performed. Aztec miners relied on the help of deities to manage the dangers inherent to the activity, including penetrating into the forbidden underworld.

Obsidian had both celestial and underworld associations. It was believed that obsidian had a celestial origin so obsidian fragments were was thought of as pieces of stars, but at the same time, it resided in the underworld. Its volcanic origin further linked it with both the underworld and the celestial realm because an erupting volcano was conceived of as a creator of stars. In a way, obsidian was considered a product of the union between the sky and the earth, something that occurs when lightning penetrates the earth. This relates it to another material that furthers the link with the celestial realm: tektites, glass objects formed when lightning strikes the ground and melts the siliceous materials and aluminum present in the soil. In this way, obsidian is dark, cold, and humid like the underworld, but also lunar and celestial (Pastrana and Athie 2014:93, 95, 102). Among the Maya, obsidian's dark color and cold quality linked it with the subterranean world or Xibalbay, where it was thought to originate (Graulich 1982:53; Recinos 1980:115).

The ancient Nahuas conceived the cosmos as divided into thirteen celestial levels and nine underworld levels, all of which were inhabited by gods and other supernatural beings. In three of the underworld levels, obsidian was an important element: Itztepetl, the fourth underworld level, was considered a hill of obsidian; the fifth level, Itzehecayan, was the place of the obsidian wind; and the ninth level, Itzmictlan, was the obsidian place of the dead. Obsidian also figured in one of the celestial levels: Itztapalnacazcayan, the place that has corners of obsidian slabs (López Austin 1980:60,63; Pastrana and Athie 2014:96). Saunders (2001:224) suggests that the idea of obsidian levels in the underworld may have been inspired by the shafts and tunnels of obsidian mines, or perhaps by the ritual use of obsidian mirrors as a way to access the underworld.

Rock crystal was also considered a precious material and it was incorporated in ritual practices. We can get a better understanding of the way this material was perceived from its description in the Florentine Codex. Terraciano (2010:51, 54) argues that this manuscript is actually composed of three texts, one in Spanish, one in Nahuatl, and a pictorial one represented by the many illustrations, and a close look at each one of them reveals multiple perspectives and levels of meaning of the subject presented. The description of rock crystal in the Spanish text is half as short as that in Nahuatl, merely stating that: "The crystal of this land is called teuilot, it is stone that is found in mines, in the mountains. Also among them arise amethysts, that are light purple stones" [35] (Sahagún 1577:XI, 358v). The two images associated to this passage include one of a man holding a bead on one hand and possibly wearing a rock crystal bracelet on the other, and a representation of a single bead. The man on the image (Figure 27a) wears a *tilmatl* or cape, a common garment worn by Mexica men, on top of a long-sleeved shirt cinched with a band at the waist; he also wears a neck adornment and the bracelet. His elaborate clothing and the adornments may indicate a high status. He sits on a mat placed at the edge of a tiled floor in front of a European-looking building overlooking a field. The bead on the second image (Figure 27b), seems to be perforated and held by a string. It stand alone in front framed by a hilly

[35] "El cristal desta [sic] tierra se llama teuilot, es piedra que se halla en minas, en las montañas. Tanbien [sic] entre estas se crian las amatistas, que son piedras moradas claras."

landscape that may indicate its source. Examples of rock crystal beads can be seen today at the Museo Nacional de Antropología in Mexico City (Figure 27c).

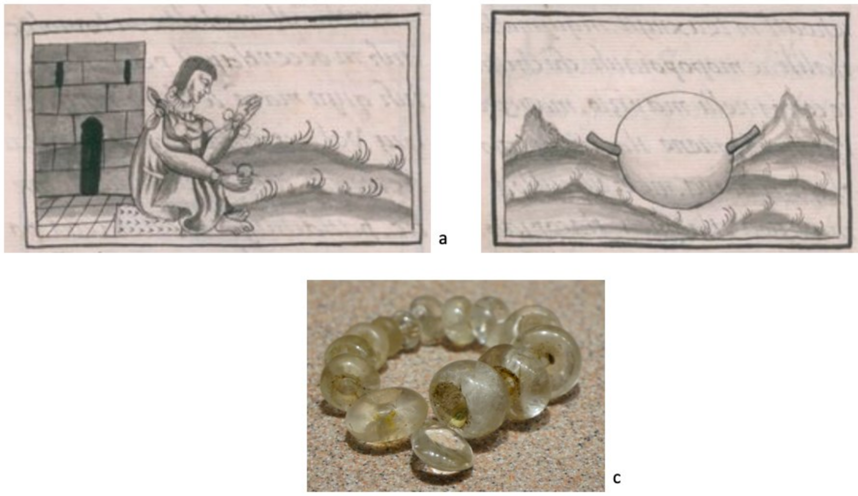

Figure 27. Representations of rock crystal or teuilotl in the Florentine Codex and archaeological examples: a) man with bracelet holding a rock crystal bead (Sahagún 1577:XI, 358v); b) rock crystal bead (Sahagún 1577:XI, 358v); c) rock crystal beads, Museo Nacional de Antropología (photo: Karime Castillo).

The text in Nahuatl offers more information:

> Teuilotl: is a crystal, it is extracted, it is buried in a hill, in a cave. Some are white, some are water purple [lilac], or purple, it can also be called tlapalteuilotl [multicolored crystal]. This crystal breaks, it is clear, it can be transparent, watery, white, pale, very clear, very pure, some others are shady, dense, adored, marvelous, astonishing, greatly esteemed, respected (Sahagún 1577:XI, 358v; author's translation).[36]

From this passage, it is clear that rock crystal was considered a precious material that was admired and held in great esteem. The qualities emphasized include its clarity and purity as well as its watery appearance and different degrees of transparency. It also indicates that amethyst was considered a type of colored rock crystal rather than a different material. In relation to this, Seler (1990:281) argues that the Nahuas used the word *teuilotl* to refer to transparent rocks in

[36] "Teuilotl: inteuilotl acan quizqui intoca, tepeio, oztoio, ce qui iztac, cequi aiopaltic, camopaltic mitoa, motocaiotia tlapalteuilotl. Inin teuilotl xapotqui, nalquizqui, naltonauel atic chipauac, chipactic, chipacaltic, chipacpatic, cequi ceio hecauhio tetzauac taçotli, mauiztic, mauizio, tlaçoti mauizioa, mauiztililo" (Sahagún 1577: 358v).

general which were as clear as water and that the etymology of the word *teuilotl* seems to be that of "round stone" in the same manner as a drop of water.

The fact that rock crystal was found and had to be extracted from caves and mountains, also linked this material with these sacred spaces. As mentioned above, minerals in general were considered integral parts of the larger entity where they originated, of caves and mountains in the case or rock crystal, and when extracted, they retained part of the mythological significance and power of its source (Saunders 2004:132). Perhaps for this reason, rock crystal was an instrument used by conjurors to discern the past, the future, and all secret things (Seler 1990:281).

In the Maya area, crystals can be found in caves, which were considered places of birth, death, and fertility, the point of access to the dwellings of deities and ancestors, as well as sources of water and maize. Crystals have also been found in association with altars, or on top of carbonized wood that could represent ceremonial burnings. Unmodified crystals appear as part of caches in the Maya area and as part of burial offerings, suggesting that the spiritual significance was in the material itself without the need of some sort of activation through modifications performed to achieve specific shapes or objects (Brady and Prufer 1999:129, 132-135,137; Saunders 2001:21).

Regarding amber, Lowe (2004a:61-67) also found a length discrepancy between the Spanish and Nahuatl descriptions in the Florentine Codex. Her analysis indicates that because of its translucid and shiny qualities, amber was viewed as water foam through which the sun could penetrate and for this reason, it was represented as a circular stone with a water current and small *chalchihuimeh* and seashells (Figure 28a). The Nahuatl version also states that amber compared well with rock crystal. Amber's association with water did not preclude it from being related to fire. Yellow amber had the property of absorbing fire, glowing, and burning; an amber piece with a flame in its interior represented in the Florentine Codex (Figure 28b), eloquently represents this property. Greenish amber was related to quetzal feathers (Figure 28c), and all types of amber had the power of attracting light objects.

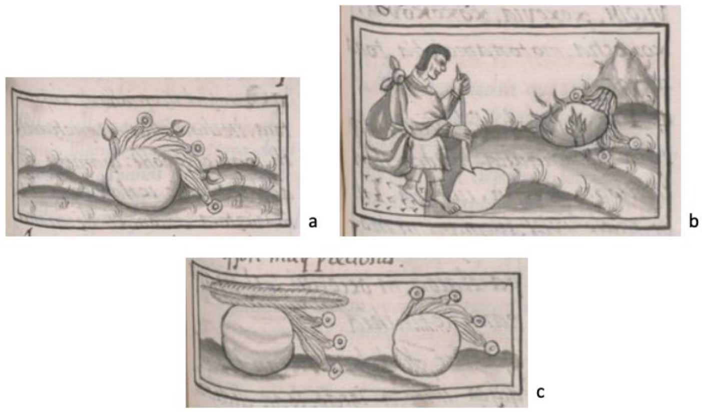

Figure 28. Representations of amber in the Florentine Codex: a) amber bead; b) extraction of amber; c) greenish amber (Sahagún 1577:XI, 359).

In addition to their cosmogonic and symbolic associations, some glassy materials were also linked to specific deities. Amber was related to the Nahua feminine deity of water who was known by the names Chalchiuhtlicue, Apozonalotl, and Acuecueyotl (Lowe 2004a:63). Amber in Mixtec is called *yuu nduta nuhu*, meaning sacred stone from the sea, further demonstrating the relation between amber and water. It was also associated with the Mixtec god Iha Nukuii, the equivalent of Xipe. Those who were to be sacrificed by fire to honor this deity were painted in yellow (Carmona Macias 1997:28).

Obsidian was also associated with a number of Mesoamerican deities. The Nahua pantheon included several deities that were related to obsidian in one way or another. These deities were Tezcatlipoca, Itztlacoliuhqui, Itztli, and Itzpapalotl. While not directly linked to this material, Ehécatl-Quetzalcóatl will also be considered given that he was associated with the divine pair Tezcatlipoca-Quetzalcóatl (Pastrana and Athie 2014:95, 99).

Tezcatlipoca (Figure 29a), the lord of the smoking mirror, was not only the patron god of Aztec royalty and rulers and the protector of warriors, but he was also a lunar deity associated with chaos. He had a variety of functions, many of which had to do with predictions of the future and uncertainty as well as justice and punishment. His characteristic attributes included an obsidian mirror, a knife, and sandals. The color black, very common in obsidian, was related to invisibility so it symbolized protection against war enemies and the strength of the warrior. The mirror represented the god's predictive qualities and was a metaphor of rulership and power, while the knife was associated with justice (Heyden 1988:222; Pastrana and Athie 2014:99-100; Saunders 2001:222). Related to Tezcatlipoca-Quetzalcóatl, was the wind god Ehécatl. A sculpture of Ehecatl and a ritual burial found inside an obsidian mine in Sierra de las Navajas, Hidalgo, indicate an association of this deity with obsidian and also suggest that this deity was a protector of miners (Pastrana and Athie 2014:81, 95, 99, 102-103).

Itztlacoliuhqui (Figure 29b) was usually portrayed with a curved jagged knife and an arrow on his cap. This deity was related with justice and divine punishment. Itztlacoliuhqui was a metaphor for sharp white ice, a kind of frozen obsidian, and he inhabited the fifth level of the underworld, where the wind is cold and cuts like an obsidian blade (Heyden 1988:221; Pastrana and Athie 2014:100).

Itztli represented one aspect of Tezcatlipoca related to punitive justice and self-sacrifice and was represented as an obsidian knife. In the case of Itztli, obsidian was both the god and the instrument for self-sacrifice, so that the same deity pierced the flesh and received the blood offering (Pastrana and Athie 2014:100, 103).

Itzpapálotl (Figure 29c), the obsidian butterfly, had wings made of, or adorned with obsidian or flint knives. It was a nocturnal deity related to sacrifice and possibly to obsidian's mythical origins. This deity represented the earth and the moon and was considered the protector of the women who died during childbirth. Itzpapálotl was also linked to war and hunting so the insignia of the obsidian butterfly was used as a military emblem in warrior costumes. Representations of this deity have been recovered in one of the workshops at Sierra de las Navajas, which suggests that she was also the patroness of obsidian knapping (Pastrana and Athie 2014:81, 101-103).

In central Mexico, an active volcano was related to the god of fire Xiuhtecuhtli (Figure 29d) and to red-mottled "meca" obsidian. Red obsidian also seems to have been associated with Xipe*,* the god of flaying, who also had associations with white flint (Pastrana and Athie 2014:95, 99; Thompson 1950:87).

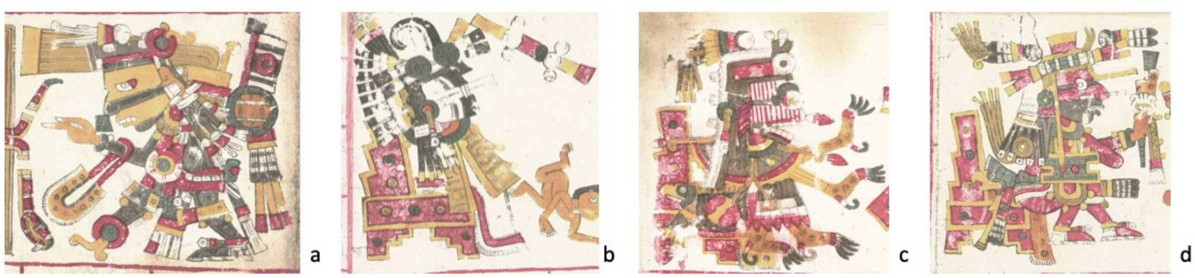


Figure 29. Mesoamerican deities associated with obsidian in Codex Borgia, Biblioteca Apostolica Vaticana (https://digi.vatlib.it/view/MSS_Borg.mess.1/00): a)Tezcatlipoca (1/0022); b) Itztlacoliuhqui (1/0071); c) Itzpapalotl (1/0068); d) Xiuhtecuhtli (1/0063).

Other Mesoamerican cultures also had deities associated with obsidian. For example, the Tarascan god Curicaueri, associated with the color black and characterized by being cold and its ability to multiply by breaking into pieces was actually, according to Darras (1998:24; 2014:63-64), a core for making obsidian blades. Possessing a part of Curicaueri, or one of the blades extracted from the obsidian core that embodied the deity, bestowed the person with legitimate power, political credibility, and religious identity (Alcalá 2012 [1574]:99). Obsidian's origin as a volcanic rock also linked it to the cult of the Tarascan creator and earth goddess Cuerauáperi.

This deity was also associated with thermal springs, which made her also a celestial goddess because the clouds and rain would emerge from these waters (Darras 2014:45, 67).

The association of rain deities with obsidian, particularly the green kind, is also seen in Oaxaca, where green obsidian was associated with the Mixtec rain god Dzahui. In times of drought, the Mixtec people made blood sacrifices by piercing their skin with an obsidian blade and offering it to the rain deity to petition for rain. Additional examples can be found in the Maya area. At the site of Piedras Negras, obsidian eccentrics shaped as the god of lightning, K'awiil, have been found in caches, while at Tikal, obsidian blades incised with the image of the same god have also been reported (Levine 2014a:176, 177).

## 5.3. Healing Properties and Medical Applications

In many parts of Mesoamerica, obsidian, alabaster, rock crystal, and other stones were considered to have medical and protective properties. Obsidian was used to heal the sick by touching their bodies with cobbles that had been naturally polished through alluvial transportation; obsidian cobbles were associated with certain body parts, so they would alleviate illnesses in specific areas of the body (Garibay 1973:151). Alabaster was thought to help to fight diseases in general (Sahagún 1577:XI, 360).

Obsidian was also part of the ingredients of certain remedies. A mixture of obsidian dust and powdered crystal was used to cure eye conditions such as cataract disease (Hernández 1959:411; Pastrana and Athie 2014:87-88). Sahagún (1577:XI, 360v; 1988:791), reported other medical uses of powdered obsidian: it was applied to wounds to prevent them from getting infected; and obsidian dust mixed with quince or other preserves was taken as a pill to treat rheumatism, mitigate fevers, and to improve the sound of someone's voice.

Obsidian's reflective properties, enhanced by water, were considered to serve as a shield against bad spirits. To avoid sorcerers from entering a house, a black blade would be placed in a bowl of water behind the entrance so that when the sorcerers saw their reflection they would fled. Obsidian was also used as a charm against eclipses by pregnant women. Eclipses were thought of as a celestial battle, which could have harmful effects, and obsidian was used as a shield against these effects perhaps because of its association with the god *Tezcatlipoca* (Garibay 1973:145-147; Pastrana and Athie 2014:84-88). Obsidian was also thought to keep away demons and venomous creatures (Hernández 1959:412; Pastrana and Athie 2014:87).

In the Maya area, while health was associated with earth, it was considered that illness could also emanate from it, so both sickness and its cure were related to earth, caves, and the materials found in them (Brady and Prufer 1999:130). For the Tarascans, obsidian was linked with mountains and water, and they believed that, just like thermal waters, the natural glass had healing and therapeutic properties (Darras 1998:9).

## 5.4. Social, Political, and Ritual Use

The diverse properties, associations, and meanings of obsidian and of materials of glass-like appearance were important in determining the objects that could be made with them, who had access to them, as well as their context of use. Many of the objects crafted in glassy materials were crucial to marking high social rank; were key components in many ritual practices, some were part of long distance exchange networks or demanded as tribute, and many were important in the process of building up prestige, wealth, and political clout (Urcid 2010:128).

Among the many artifacts made with obsidian and other glassy materials we can find a variety of objects for personal adornment including beads, earspools, labrets or lip plugs, and pendants (Brady and Prufer 1999:132). Many of these objects served as signs marking high-status and all were important elements in the constitution of personhood (Levine 2014b:16). The ornaments worn by person, in combination with other costuming elements and practices of bodily adornment, conveyed information regarding many dimensions of their individual identity, which could include social status, gender, age, wealth, achievement, and role (Finegold 2019:58; Joyce 2000:13). Clothing and ornaments could also mark important transitions in the life of an individual, or the gain of status through achievements in warfare or long distance trade (Joyce 2002:81).

In Aztec society the status of a person was differentiated by their clothing and the use of prestige items, which were regulated through sumptuary laws. Certain adornments made with a variety of precious materials were exclusively reserved for Mexica royalty. Tezozomoc (1944 [1598]:258) described an elaborate headdress worn by the Aztec ruler adorned with emeralds, green stone, amber, and diamonds, the last term referring to rock crystal. Gold labrets were normally reserved for rulers, but some royal dance costumes included translucent amber and rock crystal labrets set in gold and adorned with feathers (Olko 2014:78).

The Mexica elite had access or a variety of prestige goods that they displayed as a sign of their high status. Among the face adornments used by them were lip plugs and labrets made in green stone, amber, and rock crystal, all of which were considered precious materials and were used to make all sorts of ornaments including beads, pendants, earspools, and lip plugs. Military leaders usually wore a long labret made of amber, rock crystal, or green stone (Figure 30). Amber lip plugs, sometimes on gold mounts, were reserved for great warriors and symbolized bravery and military prowess. Mexica merchants could win the privilege of wearing them for their military merits in foreign lands (Lowe 2004a:92-96; 2004b:52-53; 2005:53; Olko 2014:77-78; Sahagún 1577:IX, 311).

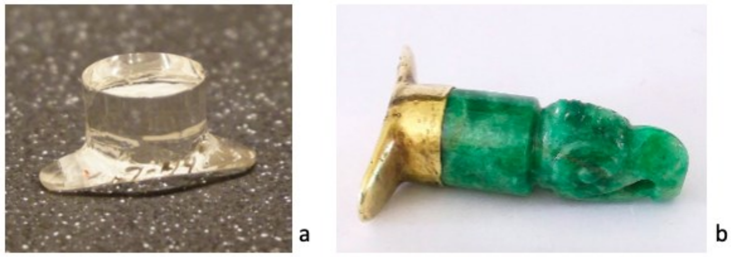

Figure 30. Mesoamerican lip plugs: a) rock crystal lip plug, Museo Nacional de Antropología (photo: Karime Castillo); b) gold and jade lip plug, Museo de las Culturas de Oaxaca (Mediateca INAH).[37]

Materials such as green stone, rock crystal, and amber were also considered precious and were reserved for the elite in other Mesoamerican societies. Sahagún (1577:IX, 324v-325), for instance, mentions that Aztec merchants took with them earspools made of both obsidian and rock-crystal (Figure 31), the first ones were meant for trade with commoners while the later were traded with foreign nobility. In the Mixtec area, lip plugs or labrets made of rock crystal, amber, jade, or gold were emblems of power worn by Mixtec rulers, and were complemented with the use of nose plugs which confirmed their high rank (Carmona Macias 1997:33).

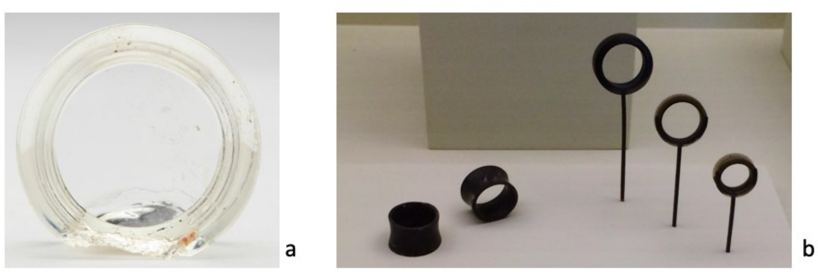

Figure 31. Mesoamerican earplugs: a) rock crystal, 1250-1521, Museo Nacional de Antropología (Mediateca INAH);[38] b) obsidian, Museo Amparo (photo: Karime Castillo).

[37] https://mediateca.inah.gob.mx/repositorio/islandora/object/objetoprehispanico%3A1503.
[38] https://mediateca.inah.gob.mx/repositorio/islandora/object/objetoprehispanico%3A16873.

Indeed, some of the facial adornments made with precious materials were also symbols of legitimate rulership. In his sixteenth-century report of the indigenous town of Cholula, Gabriel de Rojas (1581:3v) described a ceremony in which rulers got their ears, noses, or inferior lip pierced as a symbol of the legitimization of their rulership and then returned to their lands wearing lip and nose plugs as symbols of the power. Carmona Macías (1997:32-33) has suggested that because the precious materials with which these adornments were made were linked to the gods, when the ruler spoke, the precious material spoke too, and in this way the deities were speaking through the ruler.

Another material that was only used by the elite were emeralds. While there are no emerald sources in Mexico, these green gemstones were highly priced by the Aztec. There are sources of emeralds in Colombia and they may have reached central Mexico through long distance trade (Mottana 2012:182). Necklaces of emerald beads called *quetzalitztli cozcatl* were given as precious gifts to members of the high nobility, which demonstrates their high value (Olko 2014:81).

Some adornments functioned as ethnic markers. This seems to be the case of  the simple rod-shaped obsidian lip plugs that were worn by the Otomi people living in Xaltocan, in the basin of Mexico (Figure 32a). This type of lip plugs are unique to Xaltocan, so it is possible that they functioned as ethnic markers at the community level (Brumfiel et al. 1994:119, 127). In the Maya area, particularly in the Postclassic period, small disks of amber worn as nose plugs (Figure 32b) seem to have been a common accessory considering that they represent the most frequently found amber items although pendants and beads are also commonly reported; these small discs usually appear as part of funeral offerings (Lowe 2001:774-775; 2005:52-53).

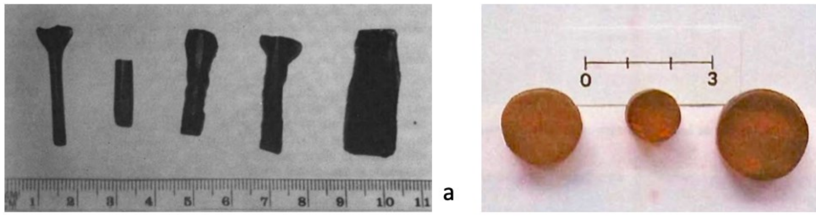


Figure 32. Adornments as ethnic markers: a) Obsidian lip plugs from Xaltocan (Brumfiel et al. 1994:116, Fig. 5.2); b) Amber nose discs from Chiapas (Lowe 2004c:56, Fig. 4).

While obsidian adornments were not normally displayed by the elite, this does not mean that obsidian was considered a lesser material. In fact, it was a material of tremendous importance economic, commercial, and military importance. Controlling its exploitation, processing, distribution, and access was crucial for Mesoamerican leaders. At the same time, many of the ritual and functional attributes of obsidian were related to important aspects of Mesoamerican cosmovision and religion; these included the renovation of seasonal cycles, birth, death, and sacrifice, nocturnal and celestial elements, warfare, protection, ritual hunting, and punitive acts of justice, as well as prediction and knowledge (Darras 1998:12; 2014:53; Pastrana and Athie 2014:83, 105).

Obsidian represented power and it played an important role in the reproduction of the governmental structure. Controllers of obsidian sources were considered to be connected to the cosmic forces (Saunders 2001:224). In both the Aztec and the Tarascan cultures, obsidian represented an instrument of royal and divine power. The ruler or *Tlatoani* of the Mexica empire carried a staff with an obsidian mirror, while in the Tarascan empire, the blades extracted from the sacred obsidian core bestowed a person with legitimate power (Darras 2014:68; Pastrana and Athie 2014:105). In the Maya area, where most of the population seems to have had access to obsidian goods, green obsidian imported from the Pachuca source appears to have been linked exclusively to the elite during the Classic period, and has been found mostly in caches and burials, suggesting it had special social significance (Aoyama 2014:131-132).

The state was involved in many of the production activities carried out in important obsidian sources such as Sierra de las Navajas, including exploitation, processing, and distribution. For the Mexica, this was true for the production of ritual objects and status items, and even more so for the production of weapons (Pastrana and Carballo 2016:335-337). The state was also involved in the procurement of materials that were not available in the region. Mayan leaders imported green obsidian from central Mexico, whereas materials like jade, amethyst, opal, and amber had to be brought from distant lands to central Mexico as part of trade or tribute. Among the articles collected by Mexica rulers depicted in the Tribute Roll (1522-1530) (Figure 33a) and Codex Mendoza (1541) (Figure 33b), there are blocks of amber the size of a brick which were demanded from the provinces of Soconusco (Lowe 2004a:82; 2005:51); amber and rock crystal labrets, sometimes set in gold, were expected from the provinces of Tochtepec and Cuetlaxtlan, Veracruz (Lowe 2004a:79, 82); while strings of beads, mainly of green stone, appear recurrently as tribute for other provinces (Charlton and Pastrana 2016:344).

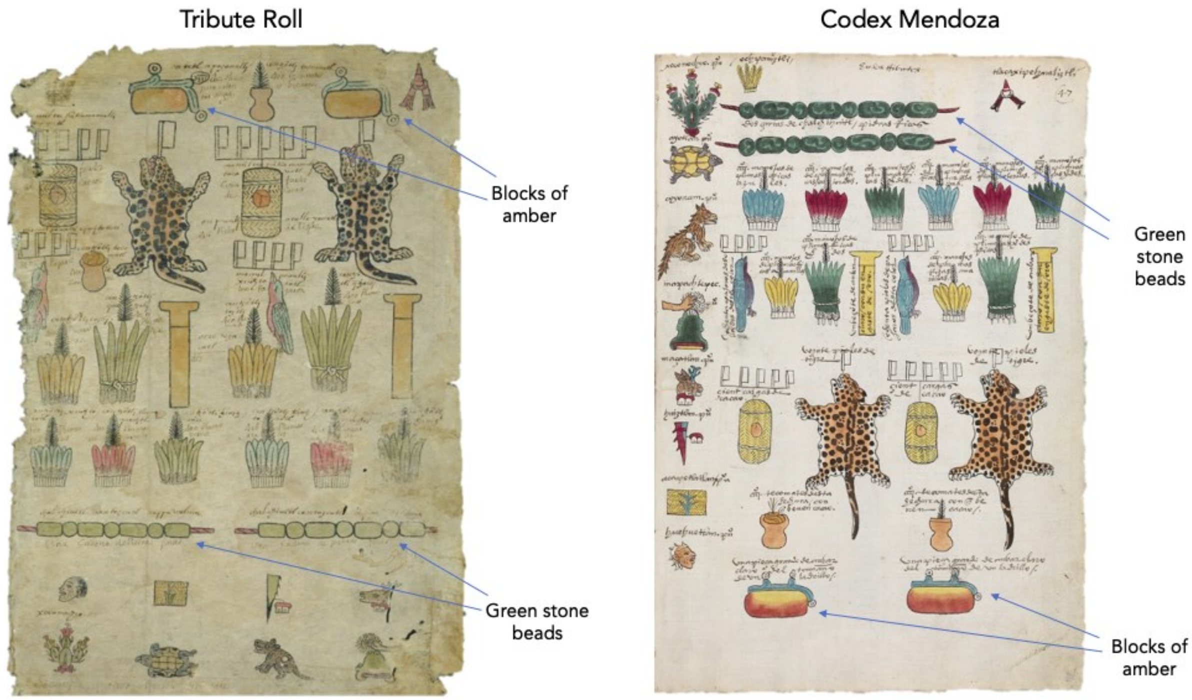


Figure 33. Amber and green stone recorded as tribute in the Tribute Roll (1522-1530:f.14), and the Codex Mendoza (1541:f.47).

The Tarascans considered that obsidian was linked to dreams and bad omens, especially in times when the kingdom was threatened by behaviors deviating from the norm, such as priests neglecting their duties. When this happened it was said that elderly women would give birth to blades in different colors and a state of chaos would prevail (Alcalá 2012 [1574]:88; Darras 2014:66). Such predictive qualities were also associated with obsidian mirrors which, as mentioned above, also allowed the viewer to connect with ancestors and esoteric knowledge, becoming in this way a source for a ruler's political power (Aoyama 2014:152). For this reason, the manufacture of mirrors was probably also restricted and controlled by the elites (Gallaga 2016:6), although the existence of *tezcanamacac* or mirror sellers in the section where pots, trinkets, and services were sold in the market of Tlatelolco may indicate that at the time of contact their use had become less exclusive (Feldman 1978:222; Gallaga 2016:18).

In relation to warfare, the most common obsidian weapons found archaeologically are projectile points, but other weapons include *macanas* with obsidian blades attached to the sides, and bifacial knives, which were usually attached to a handle (Figure 34) (Parry 2014:292). In the Tarascan empire obsidian arrowheads have been found in domestic, ceremonial, and funerary contexts. Arrows were associated with deer hunting, fire collection, and the number four, because arrows symbolized the four parts of the world (Darras 2014:60, 66).

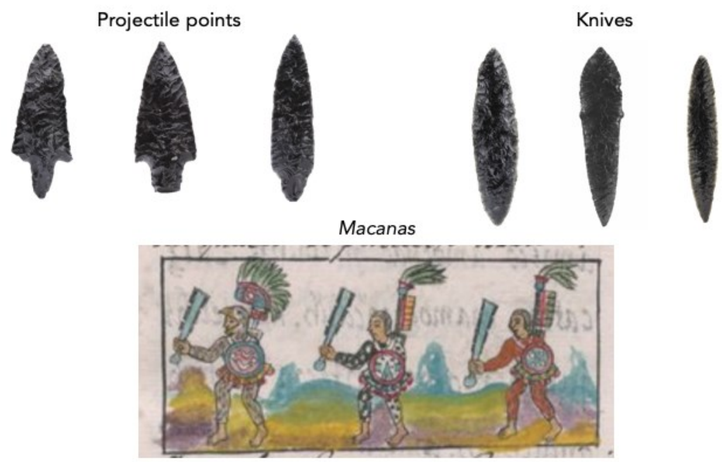


Figure 34. Examples of obsidian weapons: projectile points, 1250-1521, Museo Nacional de Antropología (top left, Mediateca INAH);[39] knives, 1250-1521, Museo Nacional de Antropología (top right, Mediateca INAH);[40] macanas held by Mexica warriors in the Florentine Codex (bottom, Sahagún 1577, IX, 313v).

As instruments of justice, obsidian blades were sometimes used by the Tarascans to punish, in the way of mutilation or death, those who committed sorcery, rape, or adultery. One of such punishments consisted on cutting with a blade the mouths of the sorcerer all the way to their ears. In the case of adultery, the ears were perforated and torn (Darras 1998:21; 2014:60).

Obsidian was used in a variety of rituals by all levels of society. It was associated with rituals of birth, passage, death, and renovation, and it was often incorporated into myths related

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[39] https://mediateca.inah.gob.mx/repositorio/islandora/object/objetoprehispanico%3A17032; https://mediateca.inah.gob.mx/repositorio/islandora/object/objetoprehispanico%3A17010; https://mediateca.inah.gob.mx/repositorio/islandora/object/objetoprehispanico%3A16098.
[40] https://mediateca.inah.gob.mx/repositorio/islandora/object/objetoprehispanico%3A17140; https://mediateca.inah.gob.mx/repositorio/islandora/object/objetoprehispanico%3A17039; https://mediateca.inah.gob.mx/repositorio/islandora/object/objetoprehispanico%3A17040.

to the creation of deities and seasonal cycles (Pastrana and Athie 2014:102, 105). One of such practices involved cutting hair with obsidian blades, which was common among the ancient Nahuas (Sahagún 1577:IX, 325; 1988:791) and in many prehispanic cultures it was linked to ritual practices. Among the Chichimec, the practice of hair cutting was associated with rituals related to a change of state, for instance, the change of status a man would undergo when becoming a Lord of the Lake. In the Relación de Michoacán, obsidian blades were used to cut the hair of the faithful during ceremonies in which captives would be sacrificed. The hair was then added to the blood of sacrificial victims and thrown to the fire as an offering to the gods (Alcalá 2012 [1574]:17; Darras 1998:12-14; 2014:53-54).

Implements made of obsidian were necessary for ritual bloodletting ceremonies. Obsidian blades and other pointed implements were used by worshipers to pierce fleshy parts of their body, rich in blood vessels, such as their ear lobes or tongues, in order to offer their blood to the gods (Parry 2014:295; Urcid 2010:178). Self-sacrifice was a pan-Mesoamerican practice with deep historical roots meant to activate relationships with supernatural entities, maintain reciprocity in a covenant between humans and the sacred, and to make petitions or fulfill sacred obligations. While its practice by the ruling elite had social significance, self-sacrifice was also performed by common people to petition for divine favors (Levine 2014b:18; Urcid 2010:178-179). In Cacaxtla, Tlaxcala, prismatic blades can be found in domestic altars in association with ritual items like censors, ceramic flutes, and elaborate pottery, as well as with other elite or ritual paraphernalia such as jade beads, obsidian lip plugs, and marine shells (Serra Puche et al. 2014:263).

In Mayan caves in Belize, the majority of the obsidian artifacts recovered are prismatic blades, objects usually associated with bloodletting rituals performed either as a form of self-sacrifice or by cutting other people or animals in order to communicate with and assuage the forces that controlled the natural world (Brady and Prufer 1999:129; Saunders 2001:221; Stemp and Awe 2014:228, 230-231). This could also be the case for the obsidian blades present in the offerings found in Templo Mayor and Tlatelolco, in Mexico City, where they could have been used to skin and dismember bodies during certain celebrations (Pastrana 2006:53). Obsidian blades have also been found in ball game courts and as part of dedicatory offerings in Cantona, Puebla (Figure 35), which suggests that they were used for specific rituals and in public ceremonies (García Cook and Merino Carrión 2005:305).

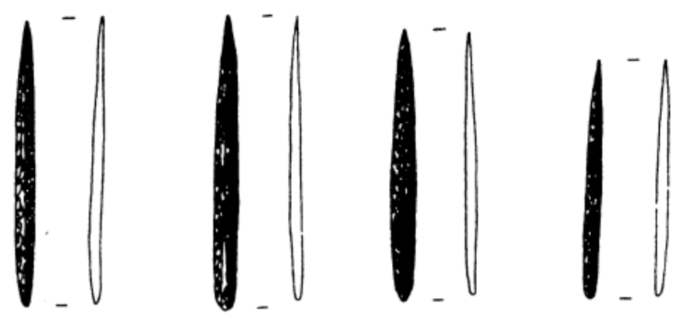

Figure 35. Obsidian blades for blood-letting from Cantona, 350-550 CE (García Cook and Merino Carrión 2005:301, detail from fig. 1).

The ceremonies dedicated to goddess Cuerauáperi involved sacrifices. In the Relación de Michoacán (Alcalá 2012 [1574]:50, 169), a blade, presumably made of obsidian, is mentioned as the instrument to sacrifice the ears to feed the fire god Curicaueri. Practices of self-sacrifice in honor to this deity usually involved other activities such as arrow-making, deer hunting, and collecting firewood for the sacred hearths. Self-sacrifice in the Tarascan empire was not restricted to the elites, commoners practiced it frequently, allowing them to communicate directly with the gods in their dreams (Darras 2014:45, 55-56).

Hernando Alvarado Tezozomoc (1944 [1598]:233-234), a descendent of Mexica nobility, mentions in his chronicle of ancient Mexico that as part of the funeral practices dedicated to fallen warriors, women brought textiles to the widow while men would present her with an earspool, a blade, a crystal, or a green stone lip plug. This was a meaningful way to honor a warrior, especially considering that objects made of such precious materials were usually left as caches and offerings in sacred places and ritual spaces (Charlton and Pastrana 2016:345).

Vessels made of obsidian, rock crystal, alabaster, marble, and travertine, which required a lot of work and time to make, were commissioned and used by elites to mark their access to prestige goods and materials. They are usually highly polished, many of them have elaborate carved designs, while others are effigy vessels depicting monkeys and other animals (Figure 36). Many of those made in travertine and alabaster have very thin walls, giving the vessels considerable translucency (Luke 2008:301-302; Urcid 2010:191, 195, 201). Alabaster vessels have been found in burial contexts in Teotihuacan (Sempowski et al. 1994:103, 152, 158, 168) and Ek Balam (Luke 2008:306); in caches and burials with elite goods in the Ulúa valley in Honduras (Luke et al. 2002:489); and as part of offerings together with other valuable objects in building dedications in Los Tuxtlas, Veracruz (Valenzuela 1945:fig. 40), and in Xochicalco, Morelos (Sáenz 1963:13, 21). In addition to being part of grave goods and ritual offerings, some authors suggest that these vessels were used for drinking during ceremonial activities and may also have functioned as markers of elite groups and regional identities (Luke et al. 2002:489).

Figure 36. Alabaster vessels: a) Mixtec tripod alabaster bowl, 1000-1521 CE, Museo Nacional de Antropología; b) three vessels from Isla de Sacrificios, Museo Nacional de Antropología (photos: Karime Castillo).

5.6. Glass-looking materials after the Conquest

The discussion above provides a glimpse into the varied symbolic meanings and associations that obsidian and other materials with a glass-like appearance had for Mesoamerican cultures and on the way these materials were used and perceived. It is clear that most of them were considered precious materials and that many of them played a key role in ritual practices.

The arrival of Europeans in America brought a whole new array of objects and materials that people in Mesoamerica had never seen before and soon after both novel and known materials acquired new meanings and associations. This, however, did not meant that old practices were completely abandoned or that local materials suddenly lost their significance. Many of the objects made with materials that had been considered precious for centuries and the practices associated with them continued after the Conquest.

Obsidian sources in Pachuca and Otumba continued to be exploited in the colonial period. This was particularly true during the early colonial period, when metal tools were scarce. Obsidian blades, scrapers, and axes continued in use at least until the seventeenth century, while new multifunctional obsidian implements were created by indigenous people in response to productive practices introduced by Europeans, such as cattle raising and metal mining (Pastrana and Fournier 1998:486, 490-491; Pastrana Cruz et al. 2019:15-32). The most notable of the latter are "macro-scrapers" with straight edges, convex or flat (Figure 37), with no precedent in prehispanic tools, that were used in the processing of animal hides and plant fibers (Pastrana and Fournier 1998:491; Pastrana Cruz et al. 2019:26). Moreover, obsidian continued circulating through indigenous networks of long-distance exchange and for many indigenous communities obsidian implements remained the preferred cutting instruments at least until the mid-seventeenth century (Forde 2017:486, 508; Rodríguez-Alegría 2008:40-41).


Figure 37. Comparison between Aztec (left) and colonial (right) scrappers (Pastrana Cruz et al. 2019:23, Fig. 2.5).

Highly polished obsidian mirrors from the contact period continued to be valued at least until the mid-sixteenth century and their production, albeit sporadic, continued until the end of the century (Pastrana and Fournier 1998:490; Taube 2016:289). Researchers studying Codex Kingsborough have found that among the precious artifacts confiscated by Spaniards from the indigenous community of Tepetloztoc in 1554 were at least ten obsidian mirrors (Taube

2016:289), which shows the importance these objects still had at the time. A rectangular obsidian mirror with a gilded wooden frame from the Contact period is now on the collection of Dumbarton Oaks; according to Evans (2010:76-77), such objects could have been commissioned by Spanish priests to be used as portable altars. An obsidian mirror in the Museo Soumaya in Mexico City showcasing an oil-painting scene of the garden of Gethsemane (Figure 38) shows another type of use for these artifacts in the colonial period.

Figure 38. Anonymous, Prayer in the garden of Gethsemane (c. 1640-1660) on obsidian mirror (900-1521), Museo Soumaya (photo: Karime Castillo).

The perception of minerals as infused with the power and ritual qualities of their sacred place of origin also seems to have remained at least during the early colonial period. An example of this could be the practice of bestowing power and life to a figure by giving it a symbolic heart made of a precious material. Callaway (1990:224) and Weismann (1950:16-17) have interpreted in this way a flat disc held in front of her chest by the virgin at the bottom of the atrial cross of the sixteenth-century convent of Acolman, in Oaxaca (Figure 39).

Figure 39. Detail of the atrial cross of the convent of Acolman (Weismann 1950:16, Fig. 7).

The use of amber nose plugs in many Mayan communities also continued after the conquest. Friar Francisco Ximénez (1929:349), who was in New Spain in the 1540s, found that the old men in the town of Chiapa had their noses partially open and dressed with an amber "window." Fray Diego de Landa (1898:139, 179, 203, 228, 245) also reported seeing men and women wearing them in several towns in Yucatán. These ornaments remained in use at least until the late seventeenth century. Don Juan de Villagutierre Soto-Mayor (1933:243), who arrived in New Spain in 1695, mentioned that women in the town El Lacandón, Chiapas wore amber circles the size of a *real* coin on their noses, specifying that the material was also used to make rosaries (Lowe 2004c:49). The use of amber to make rosaries had been documented by Friar Alonso Ponce at the end of the sixteenth century (San Juan and Ciudad-Real 1872 [1584]:478). The practice was later documented in the eighteenth century by Friar Francisco Ximénez (1967 [1722]:332), who commented that indigenous people of Guatemala worked amber, which was a very aromatic stone, into rosaries, figures, and other curiosities.

Friar Ximénez (1967 [1722]:322-323) also documented the use of alabaster or *tecali* to make figures of saints, small boxes, ink bottles, and *salvaderas* or sandboxes for writing. *Tecali* was also adapted to a European use as a material to make windows and skylights, because when cut into fine sheets and polished, it allowed light to pass through (Fernandez de Echeverria y Veitia 1962 [1780]:293). Friar Ximénez (1967 [1722]:325-326) also mentioned a source of very clear and transparent rock crystal in the valley of Tocoy, Guatemala and lamented that no Spaniard knew how to work it considering the material's potential for the making of curiosities. A polychrome *tecali* stone bowl and plate in the collection of Museo Soumaya (Figure 40) represents an example of the continuity of lapidary work of Mesoamerican tradition combined with European decorative techniques.

Figure 40. Bowl and plate of tecali stone with gold and polychrome decoration, c. 1601-1650, Museo Soumaya (photo: Karime Castillo).

The belief that several stones had medical properties also prevailed through the colonial period and continues today in some communities. Vetancourt (1870 [1698]:64) documented that amber was used to cure the heart in the late seventeenth century. In 1813, the priest of Yaxcabá, Bartolomé del Granado Baeza (1941 [1813]:228), reported to the Ministerio de Ultramar[41] that the Mayans used a piece of clear and transparent crystal called *zastún* to see the origin of diseases and discomforts caused by sorcery. Today, Otomi healers pass crystals over the body of a person to pull out a sickness (Brady and Prufer 1999:130-131), while the Yucatec Mayan

[41] Overseas Ministry.

continue to use the crystal divination stone *zastún* to make medical diagnoses (Aguirre Beltrán 1992:54).

Some communities in Mexico continue to associate crystals with certain powers derived from the earth. In the Huaxtec region, for example, shamans are expected to see the future and to diagnose the problems or ailments of their clients through methods like crystal gazing. For this reason, quartz crystals called *tescatl* or mirrors are an important part of a shaman's ritual paraphernalia (Sandstrom 1991:235). Yucatec Mayan shamans also have crystals in their ritual tool kits for divination and the acquisition of knowledge. In addition, The use of crystals for protection also continues today albeit mixed with European beliefs. Contemporary Mayans use amber to make amulets to protect children against the "evil eye," a popular belief from Spain that took root in the Americas (Lowe 2004a:55).

5.7. Some Reflections on the Perception of Artificial Glass

From these examples, it is clear that glassy materials retained much of their importance and symbolic meaning after the Conquest and in some cases, reminiscences of their ritual significance have lingered until today. It is within this context that the perception of artificial glass needs to be considered.

Just like many of the materials discussed in this chapter, glass has the smoothness, reflection, shimmer, and translucency that were so valued by people in Mesoamerica. Like obsidian, it is strong, sharp, durable, and has conchoidal fracture. Colorless glass can be as transparent as the purest rock crystal. But in terms of color, thinness, and variety of attainable shapes, glass went above and beyond anything indigenous people could have ever imagined. It only makes sense that at the time of Contact any glass piece would have been considered a marvel, and indeed, objects like glass beads became important trade objects for many indigenous groups, as will be discussed in Chapter 10.

But perhaps the major differences were in the origin and the technology to work them. Instead of extracting it from sacred landscape features, glass had a more humble origin in sand. Yet, in its manufacture, it became a sort of liquid fire that could be manipulated and blown. Knowing that amber was considered water foam through which sunlight shone and was thought of as having a spark of fire inside, what could have been the conception of hot blown glass that glowed? Furthermore, it completely changed color once it cooled down, becoming clear and transparent as rock crystal, or acquiring colors unavailable in local minerals, such as deep cobalt blue or aquamarine.

While glass might not have come from a sacred source, the way it was worked must have seemed magical and glass artisans must have appeared as sorcerers or shamans capable of shaping fire at will. This was another fundamental difference between glass and the materials Mesoamerican people knew. Making vessels and rounded objects in obsidian, rock crystal, or alabaster was both difficult and time-consuming, so watching a blob of glass blow up and grow in a few seconds must have been absolutely astonishing. All the colors of glassy materials found in nature in Mesoamerica that were significant for people in Mesoamerica could also be replicated in glass, but glass also offered the possibility of producing shiny, translucent artifacts in a much wider variety of colors and shapes. The resulting products, with impossibly thin and perfectly rounded walls would have been equally dazing. Many questions remain to be considered regarding the initial perception of artificial glass, as well as its adoption, adaptation, and use. The chapters that follow will provide some answers.

# 6. GLASS PRODUCTION IN NEW SPAIN

## 6.1. Glassmaking in Spain

To understand the arrival and development of glass technology in colonial Mexico, it is important first to comprehend how glass was developed in Spain, the place of origin of the first glassmakers to arrive in the Americas. This section provides background information regarding the history of glassmaking in Spain, noting the main glass production centers and the main characteristics of their products. This is important if we considering that the glassmakers who arrived in the Americas throughout the colonial period came from different parts of the Iberian peninsula, so familiarity with Iberian glass production is necessary to take into account the varied influences that came into play in the production of glass in colonial Mexico.

The production of glass in early modern Spain was itself influenced by a rich history of cultural interactions and by a complex network of methods that resulted in a particular technology which was imported to the Americas. At its zenith, the Spanish empire included territories from the Netherlands in the north and Italy in the south, as well as outposts in Africa and Asia, which facilitated the movement of people, products, and technologies into and out of Spain. The diversity within this vast territory enriched peninsular craft production. The following summary seeks to highlight the movement of artisans and glass products in the Iberic peninsula before and during the early modern period to illustrate some of these influences.

Although there are glass artifacts in the Iberian peninsula which date to the third century BCE, glass working did not became a well-established industry until the introduction of glassblowing by the Romans in the first years of the common era (Gudiol and Artiñano 1935:44, 47). After the fall of the Roman Empire, Iberia was dominated by Visigoth and then Muslim groups. North Africans exerted a profound influence on Iberian glass, particularly in Andalucía, where glass blown by Hispano-Muslims became a tradition that underwent little change until modern times (Frothingham 1963:13-14; Gudiol and Artiñano 1935:48). The multiple influences continued in the Medieval period. Between the thirteenth and the sixteenth centuries, for instance, glassmakers from Flanders, Germany, and France joined local artisans to provide churches with stained glass windows, traveling from city to city and setting furnaces within or near the building for which the windows were made (Frothingham 1963:16).

At the beginning of the Early Modern period, during the reign of Ferdinand and Isabel (1479-1516) the import of foreign goods was forbidden in order to protect local industries, but this changed during the reign of Charles V (1516-56), who encouraged imports and levied taxes on Spanish manufactures. His succession united Spain and Flanders and enabled the relations between Spain and artisans from Flanders, France, Germany and Italy despite royal attempts to limit the work of foreigners (Barrera-Osorio 2006:58). This had a direct impact on the glass industry by fostering the interchange of glassworkers and the spread of glass *à la façon de Venise* (Frothingham 1963:14). During the sixteenth century, Spanish glass in general was greatly influenced by Venetian glass; this can be seen in decorative motifs such as glass trails, knot designs, application of *lattimo*[42] canes and trails, and golden paint accents that had their origin in the island of Murano (Ainaud de Lasarte 1952:348; Doménech 2004:100).

In Spain, glass factories prospered in areas where essential materials such as sand, halophyte plants,[43] and firewood were abundant and which were also close to routes of transportation (Frothingham 1963:16). One such region was Catalonia, Barcelona in particular, where glass *à la façon de Venise* was made. Catalonia was already an important glassmaking

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[42] The term *lattimo* refers to opaque white glass.
[43] Halophyte plants are salt-tolerant plants the ashes of which were used as a flux in glassmaking.

center at the beginning of the fourteenth century and by the fifteenth century glassmakers shared a guild and confraternity with the esparto grass weavers,[44] becoming an independent guild in 1594 (Gudiol and Artiñano 1935:50-52; Planell 1948:75, 79). While Catalan glassmaking was based on an outstanding medieval tradition, the region became the leading interpreter of Muranese glassmaking innovations in Spain during the sixteenth and seventeenth centuries (Doménech 2004:85). Catalan glass entered an era of splendor in the sixteenth century, when it was shipped to Castile, the Americas (also known as West Indies), France, and Italy, among other places (Frothingham 1963:30, 40; Iglésies 2002:219). To produce Venetian-style crystal glass, Catalan artisans used a variety of halophyte plants but mostly *barrilla* from Alicante, famous among glassmakers for its excellent quality. Spanish *barrilla* was exported throughout Europe during the sixteenth and seventeenth centuries, its superiority over other kinds was recognized in Venice and places making Venetian-style glass such as Flanders, England, and France (Frothingham 1963:II). The glass *à la façon de Venise* made in Catalonia was meant to be displayed as part of the luxury tableware and was collected by aristocrats and royalty (Ainaud de Lasarte 1952:348; Doménech 2004:88). The export of Catalan glass began to decline around 1650, when production became more focused on utilitarian objects for local consumption (Frothingham 1963:48; Gudiol and Artiñano 1935:53).

Castile was another area where large forested areas provided enough fuel to allow the flourishing of glassmaking in places like San Martin de Valdeiglesias, Cadalso, and Recuenco (Doménech 2004:105). During the first years of the seventeenth century, Italian and Flemish glassworkers flocked to Spain, many of them settling in Castile, where there was a guild of glass merchants that included both glassmakers and potters (Frothingham 1963:60; Gudiol and

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[44] In Spanish *esparteros.*

Artiñano 1935:70). The main market of these furnaces was Madrid, home of nobles who were avid consumers and collectors of glass. A number of glass factories flourished in Cadalso, a hilly area in the province of Madrid rich in forests and deposits of the refractory clays needed for the furnaces and crucibles. By the early sixteenth century, Cadalso had become so noted for its glass products that it was given the name of Cadalso de Vidrios and it supplied the entire kingdom. The glass made there was considered to be of high quality and second only to that made in Barcelona (Frothingham 1963:60, 63; Gudiol and Artiñano 1935:75). Castile became another important center for the production of glass *à la façon de Venise*. Most glass produced in workshops near Madrid was blown in the Venetian style, showing a tendency towards decolorized glass and decorated with patterns similar to those made in Murano. Other products resembled Italo-Flemish and Catalan glass. The movement of glass artisans between Flanders and Spain was not always from north to south; Spanish glassmakers also migrated to Brussels (Doménech 2004:105; Frothingham 1963:63-64).

During the last years of the seventeenth century the glass industry in the region near Madrid began to decline. Glass made *à la façon de Venise* waned in demand as wheel-engraved and gilded crystal from France and Central Europe became increasingly popular (Doménech 2004:108). As Spanish factories were unable to supply this type of glass, all of it had to be imported until a glass factory called Nuevo Baztán was established at a site near Madrid, where many glassblowers who had once worked in Saint Gobain, France were employed. Soon after, a royal grant was issued that prohibited the import of foreign crystal to Castile and the Nuevo Baztán became the main supplier of engraved glassware to Madrid and other parts of Spain. Some of these products were also shipped to the Spanish colonies in the Americas. A shortage of fuel supplies forced the factory to move to the Cuenca mountains, but the deficient raw materials available there affected the quality of glass mixtures, and production ceased around 1728 (Frothingham 1963:66-67; Gudiol and Artiñano 1935:78-79). An important production center in Segovia during the eighteenth century was La Granja de San Ildefonso, which became very successful and functioned under royal patronage. La Granja provided glass for the royal palace, and sold its wares throughout Spain and to other countries (Gudiol and Artiñano 1935:80).

Glass was also made in Mallorca since the Phoenician and the Roman occupations and continued in the Middle Ages. In the Early Modern period, the glass produced in Mallorca, like in most of Europe, was influenced by Venetian glass trends, which came mostly via Catalan glass and glassmakers, but also directly from Venice (Capellà Galmés and Albero Santacreu 2015:143; Giménez Raurell 1996:20, 23). The Venetian glassmaker Domenico Barovier, who moved from Barcelona to Mallorca and later to Castile (Doménech 2004:111), provides an example of the way glassmakers may have propelled multidirectional influences from one place to another.

In Valencia there is evidence of glassmaking since at least the third century CE (Sánchez de Prado 2015:23), but it was only in the seventeenth century that the glass industry became more active. The area had sands suitable for glassmaking and, as mentioned above, Alicante was the main supplier of *barrilla* to Spanish and foreign glass factories; however, the glass made in this region did not enjoy the recognition and reputation that Catalan glass possessed. Valencian glassware was quite ordinary in its quality and was made for everyday use; fine glass was imported from Venice and other centers until the eighteenth century, when a workshop obtained royal permission to ship their products free of export duty to foreign countries and began selling glass all over Spain (Doménech 2004:112; Frothingham 1963:46-47; Gudiol and Artiñano 1935:63).

In the south of Spain glass was made since the Roman occupation. Between the sixteenth and the nineteenth centuries, ordinary green glassware with Islamic influence was blown at small furnaces, the most important of which were in Castril de la Peña, Puebla de Don Fadrique, Pinar de la Vidriera, and Almería (Doménech 2004:111; Gudiol and Artiñano 1935:67). Andalusian glass is characterized by its thin green walls and for having many features that result from its close ties to ceramic factories (Doménech 2004:109; Frothingham 1963:52, 54, 56). While glass production in this area retained its Islamic roots and was meant for ordinary use, some glass workshops appropriated elements from the Muranese tradition into their products, particularly in Seville, where trade in Venetian, Flemish, and Catalan glass influenced local glass production (Ainaud de Lasarte 1952:364; Doménech 2004:85). Glassmakers like Juan Rodríguez, who came from Cadalso and worked both in Venice and in Barcelona before establishing himself in Seville played a crucial role in spreading techniques and styles from one workshop to another (Frothingham 1963:57).

In the eighteenth century, Bohemian glass became popular all over Europe, overcoming Venetian competition. European elites began to prefer Bohemian glass at their tables, stimulating some glass workshops to produce glass *à la façon de Boheme*. Bohemian glass vendors also opened permanent trading centers in many European cities, including port cities like Cadiz and Seville from where Bohemian glass products were sent to the New World (Capellà Galmés 2015:215; Frothingham 1963:58; Langhamer 2003:40, 43).

This brief review shows how Spanish glass production developed within a complex network where artisans were continually exposed to influences from different parts of Europe, particularly from Venice, but also from Flanders, France, and later Bohemia, as well as from Islamic traditions in the south. Traveling glassmakers were paramount in facilitating the movement of glass recipes, technical skills, and decoration techniques from one production center to another. This diversity of influences resulted in the particular technology that eventually made its way to the Americas.

## 6.2. The Arrival of Glass and Glassmaking to the Americas

While glass itself, albeit of volcanic origin, was nothing new in Mesoamerica, the technology to make it artificially, and the wide array of possibilities that came with glassblowing in terms of shape as well as in diversity of color, thanks to the addition of metallic oxides to the melt, were unprecedent in the American continent. The first manmade glass objects introduced into the New World were glass beads and a few other glass objects that the first Spaniards brought with them to use during their transatlantic journey. Christopher Columbus and other European explorers used them during their first encounters with indigenous populations, which always included a type of barter, advantageous to the colonizer, known as *rescate*. The articles offered by the Spaniards were low-value by European standards and included glass and metal beads amongst other things, which they exchanged for food and other local goods (Kelly 1992:7). Europeans had used this kind of exchange in the west coast of Africa before their arrival to the New World (Fernández 1990:39-40; Vidales Giovannetti 2009:282). The exchange of beads between Europeans and indigenous population appears in many of the chronicles written in the sixteenth century by the Europeans making their way through the New World (e.g., Colón 2012 [1493]; Cortés 1993 [1519]; Díaz del Castillo 2011 [1575]; López de Gómara 1943 [1553]).

Not long after the arrival of glass beads came the glassmakers themselves. The first notice of a glassmaker documented in the viceregal territory dates to February 12, 1535:[45] an artisan with the name Rodrigo Despinosa (de Espinosa) who appears in a list given to the viceroy that includes all the married men in the bishopric of Mexico, whose wives were not with them (Paso y Troncoso 1940:151). Towards the end of that year and shortly after the arrival of viceroy Antonio de Mendoza, various Spanish craftsmen, including glassmakers, came to New Spain "to ennoble the province" (López de Gómara 1943 [1553]:489). It is unclear for how long Rodrigo de Espinosa remained in Mexico City, but by the 1540s he had moved to Puebla, where he was listed as a resident that did not have indigenous people under his charge. His declaration also stated that, at that point, he had been in New Spain for nine years (Icaza 1923:191).

It is not known when or where the first glass workshop was established in the Americas. Considering that Rodrigo de Espinosa apparently spent several years in the capital before moving to Puebla, it would make sense that he first attempted to establish glassmaking in Mexico City, but the first actual reference to a glass furnace in a historical document refers to the one he established in the city of Puebla and dates to 1542 (Fernández 1990:44). Only twenty years after the fall of Tenochtitlan, glass production was already underway in at least one if not two major cities of New Spain.

During the second half of the sixteenth century, and later in the seventeenth century, there were other attempts at glass production outside of Mexico City and Puebla. One of them was at the indigenous town of Ameca in Jalisco, where the glassmaker Benito de Espinosa[46] had a glass furnace in 1576. The indigenous residents of the town were complaining that the Spaniard had taken over the town's community house to put the furnace, that he kept cutting down trees of

[45] AGI, Patronato, 180, R.61, f. 4v.
[46] It is possible that Benito was related to Rodrigo de Espinosa.

Castile for fuel, and that he employed Indians without paying them. This was not the first complaint made by the villagers, the viceroy had already asked Benito de Espinosa to move his workshop to a Spanish town but the document does not specify how long he resided there, nor when he left the town (Fernández 1990:228; Martins Torres 2019a:199).[47] However, the glass workshop in Ameca did not seem to have lasted long. No further information about this workshop has been found from later centuries. Eventually, the glass industry was eventually formally re-established in Jalisco at the beginning of the nineteenth century (Flores Barba 2007).

Later, in the seventeenth century, there was a workshop active in San Luis Potosí owned by Pedro Torres C., where master glassmakers Joseph de la Cruz and Pedro Sanchez E. worked; the first one was reported in 1629, and the second one in 1639, although at that time he was in jail. It is possible that his workshop is the same that appears in 1630 under the management of Pedro de Tejada, unless there was a second workshop (Galván Arellano 1999:160, 176-177). Fernández (1990:86-86) reports that remains of a glass furnace were excavated in San Luis Potosi by INAH, but unfortunately the finds were not published. It is not known for how long the glass workshop in San Luis Potosí was active, but it was no longer there the following century (Galván Arellano 1999:174).

Thus, throughout most of the colonial period, the two major glass production centers were Mexico City and Puebla. As Martins Torres (2019a:192) has argued, the Crown was invested in stimulating this industry in the New World, primarily because of its links with the processing of precious metals. Glass production, indeed, became an important New Spanish industry early on. By 1574, the viceroy D. Martín Enríquez already included glass as part of the *cosas de la tierra* (things from the land), subject to the collection of the *alcabala* tax, which was

[47] AGN, General de Parte, vol.1, f. 204.

applied on both incoming imports from Europe and locally produced goods (García Icazbalceta 1886:192-193). Including glass products as part of the "things from the land" as opposed to referring to glass as an import indicates that the local glass industry already stood firmly in New Spain before the end of the sixteenth century.

Recent historical research has brought to light the paramount place that Mexico City had in the making of glass products. While previous publications had considered Puebla as the main glass production center in colonial Mexico (*e.g*., Fernández 1990; Martínez Peñaloza 1972; Romero de Terreros 1951; Rubín de la Borbolla 1974), recent research by Martins Torres (2019a and b), Peralta Rodríguez (2004, 2013, 2014, 2018), and Peralta and Alvizar (2010) has debunked this idea. As Martins Torres (2019a:53) argues, such conception was promoted by nationalistic discourses around popular art that were prevalent in the twentieth century.

The following sections discuss the development of the glass industry in Mexico City and Puebla emphasizing the varied origins of the glassmakers. This is important because, glass in New Spain, both as a technology and as a product, was form the very beginning subject to multiple influences. Not only was the technology in the Iberian peninsula itself constantly responding to the production from other parts of Europe and the Islamic world, but once the technology took root and began to flourish in New Spain, glass continued to be subject to global influences through transoceanic trade. Puebla was an intermediate stop for merchants traveling from Veracruz to Mexico City, carrying products mainly from Spain, and also other parts of Europe, while both Mexico City and Puebla were important hubs for merchants who transported products from the Manila Galleon along a commercial highway that connected Acapulco on the Pacific coast with Veracruz on the Atlantic side (Schurz 1985: 310). Thus, both cities were important nodes in the movement of goods across the Pacific and Atlantic oceans. For these reasons, the study of glassmaking in colonial Mexico needs to be done taking into account both the local and the global contexts (Martins Torres 2019a:34). While this section will focus more on the artisans, Chapter 10 will look at the influences exerted by travelling goods.

### 6.3. Glass Production in Mexico City

Although we do not know the exact year when glass production began in Mexico City, we know that Rodrigo de Espinosa, the first glassmaker in the Americas, was living there in the 1530s. This artisan from Guadahortuña, near Granada, was the legitimate son of Francisca Mellada and Cosme Despinosa (Icaza 1923:191). He was married and had two sons, but the records from both Mexico City (Paso y Troncoso 1940:151) and later Puebla (Icaza 1923:191) state that his wife was not with him. Martins Torres (2019a:283-290) tracked down Rodrigo de Espinosa and his family in Spain. At the time of his first departure to the New World, him and his parents were living in the town Castillo de Lecubín in the province of Jaén. His father, Don Cosme de Espinosa, was also a glassmaker born in Espinosa de los Monteros, province of Burgos, in the north of the Iberian peninsula. Don Cosme de Espinosa's glass business had expanded to the Canary Islands, where he had a glass workshop that he transferred in 1549 to another family member, Baltasar de Espinosa. The glass made there, which included bottles, tableware, and containers for distillation, was sent to other islands and to the New World (Rodríguez Mesa and Macías Martín 2012:99). Hence, Rodrigo de Espinosa came from a well-established family of glassmakers who ran a successful business in various regions.

Fernández (1990:43) suspected Rodrigo de Espinosa to have participated in the conquest expeditions. His name, indeed, appears in a list of conquerors that travelled with Narvaez to the territory that would become the viceroyalty of New Spain to apprehend Hernán Cortés after he had travelled to continental land without permission. In this list, however, his craft is not specified as it is for other people in the list (Dorantes de Carranza 1902:383). If this was him, it would mean that he arrived in continental land in 1520. His activities during and after the conquest are a mystery, as is the time he spent in the capital before moving to Puebla, but it seems that he travelled back to Spain sometime between 1535 and 1538 because on July 20th of that year, while in Guadahortuña, he notified the Casa de Contratación[48] of his return to New Spain accompanied by his brother, Felipe de Espinosa, whose occupation is unknown (Martins Torres 2019a:286).[49] The whereabouts of the glassmakers that arrived shortly after Viceroy Mendoza mentioned above are also unknown.

There are no more records of the arrival of new glassmakers to the capital until the 1550s, although Martins Torres (2019b:124) reports that someone with the last name Vergara was paid for the materials and the mounting of the windows of the cathedral in 1539; however, it is uncertain if this person was a glass artisan. Later, in 1557, a glass master from Seville[50] named Juan Rodriguez obtained *licencia* or permission to travel to New Spain to establish a workshop in Mexico City, taking with him two glass artisans (*oficiales*) to help him, as well as his wife and unmarried children.[51]

The following decade, more glassmakers followed. Glassmaker Hernando de Espinosa[52] travelled to New Spain in 1560 accompanied by his servant Pedro Peinado, who was single and came from Ladrada (La Adrada) in Ávila (Romera Iruela and Galbis Díez 1980:20). On that same year, there was another glass artisan in the capital whose date of arrival is unknow, Guillén

[48] The Casa de Contratación was the institution that monitored all the commerce, fleets, and people bound for the New World (Ladero Quesada 2002:9).
[49] AGI, Contratación, 5536, Libro 5, f. 126r (2).
[50] According to Martins Torres (2019b:124), this artisan resided in Coria Extremadura before moving to Seville.
[51] AGI, Indiferente, 1965, L.13, f. 386v-387.
[52] Perhaps this glassmaker was also related to Rodrigo and/or Benito de Espinosa.

de Almas from Catalonia.[53] He was married to an indigenous woman who was the owner of the house where they lived in the *barrio* of the *tianguis* (market) of San Juan. A couple of years later, he received from the Cabildo of Mexico City a *solar* or piece of land (Boehm de Lameiras 1987:27; O'Gorman and Novo 1970:367, 386). Then in 1566 he obtained permission from the Real Audiencia of New Spain to travel to the Viceroyalty of Peru to collect some colorants and tools that had been sent to Lima from Castile. He mentioned that he would return to Mexico City, where he made glass with his partner Pedro Peinado and kept a populated home (Fernández 1990:49; 1994:79).[54] This could be the same Pedro Pintado who arrived in 1560 and it is possible that at some point he stopped working for Hernando de Espinosa. Later, in 1569 Pedro del Huerto from Seville, wrote to the king of Spain asking for permission to return to Mexico City after traveling to Castile to get tools for his trade, where he had established a glass furnace six years before, and to bring two other glass artisans (*oficiales*) back with him.[55] Pedro del Huerto was still active in 1571, and more glassmakers continued to establish themselves in the capital, such as Juan de Espinosa from Seville.[56] By the end of the sixteenth century, two more glassmakers with the last name del Huerto, maybe related to Pedro del Huerto, were working in the city, Miguel and Mateo del Huerto (Fernández 1990:258; Sánchez Arreola and Zárate 2015:151).[57] There are records of more glass artisans in the capital dating to 1596, which include Mateo Ruiz (Maldonado Mares and Pineda Mendoza 1995:194)[58] and Juan de Quiroz,[59] as well

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[53] AGN, Indiferente Virreinal, caja 5463, exp.58, f. 1.
[54] Fernandez (1990:49) believes the trip involved the transfer of a full glass workshop rather than just collecting the colorants and tools, although in his later publication (Fernández 1994: 79) he mentions that Guillen de Almas finally decided to return to Mexico City.
[55] AGI, Indiferente, 2052, n.34, f. 1.
[56] AGN, Inquisición, vol. 91, exp. 5, f. 98.
[57] AGN, Reales Cédulas Duplicadas, Vol. III, exp. 162, f.122; AGN, Inquisición, vol. 91, exp. 5, f. 76v.
[58] AGN, Matrimonios, vol. 119, exp. 9, f. 53.
[59] AGN, Indiferente Virreinal, caja 5990, exp. 38, f.1.

as more glass artisans coming from the Iberian peninsula, such as Blas Hernández from Castile,[60] and Xayme del Valle, from Catalonia; the last one was making glass of such high quality that it was said it could be compared to the famous Venetian glass (Fernández 1990:60).[61] The high quality of his work convinced the *cabildo*[62] that glassmakers should receive support so that they would stay in New Spain practicing their craft.[63]

The sixteenth century saw the arrival of at least fifteen glass makers[64] coming from Seville, Catalonia, La Adrada in Ávila, and Castile. This reflects not only the growing demand for glass in New Spain, a tendency that continued in the subsequent century, but also the varied places in the Iberian Peninsula from where these artisans came, and thus, the technological and stylistic influences that began to forge the glass industry in the viceroyalty. None of the historical documents specifies the location of glass furnaces and only three records specify where glass artisans lived: the barrio de San Juan (Figure 41), where the aforementioned Guillén de Almas and Mateo Ruiz lived, the latter in 1580 (Maldonado Mares and Pineda Mendoza 1995:194); and Portal Nuevo, where Blas Hernández lived in 1596.[65] Although the location of the last area is unclear,[66] it should be noted that the barrio de San Juan was located outside the first *traza*, a quadrangle in the center of Mexico City that marked the limit between the Spanish city (inside the *traza*) and the surrounding indigenous towns or *barrios* (neighborhoods). The *traza* also referred to the grid design of the streets and plots inside it, the center of which was occupied by

[60] AGN, Indiferente Virreinal, caja 5990, exp. 38, f.1.
[61] AGN, Reales Cédulas Duplicadas vol. III, exp. 161, fs. 120v-122.
[62] City council.
[63] AGN Reales Cédulas Duplicadas, vol. 3, exp. 161, f. 120v.
[64] Martins Torres (2019b) includes as a glassmaker an apprentice of *candilero*, a term that can refer to both a flame glass artisan or a candlemaker. Given this ambiguity, artisans referred to as *candileros, candeleros,* or other variants that do not explicitly mention glass were not considered here.
[65] AGN, Indiferente Virreinal, caja 5990, exp. 38, f.1.
[66] Portal Nuevo could refer to Portal Nuevo de Mercaderes, in the Plaza Mayor.

the Plaza Mayor (main square), the cathedral, and the main government buildings (Dávalos 1991:57).

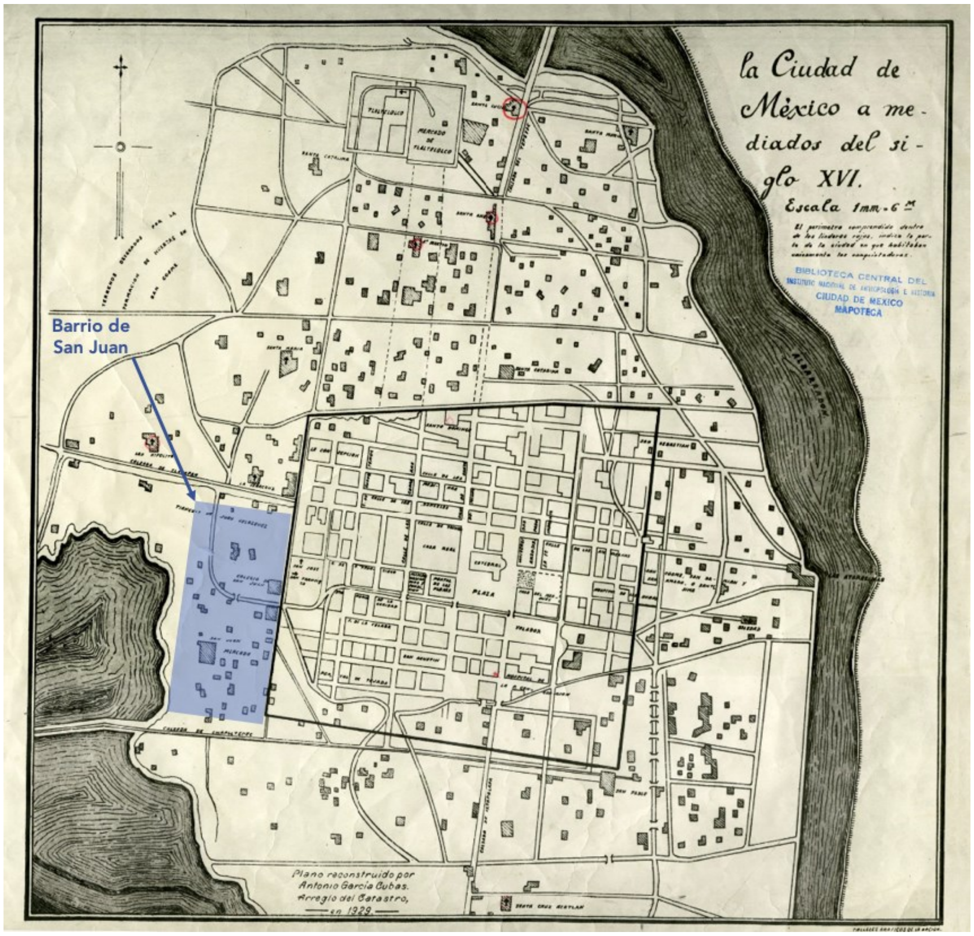

Figure 41. Location of Barrio de San Juan (blue) in 16th-century Mexico City (modified from a map by Antonio García Cubas, 1929, Mediateca INAH).[67]

Glassmaking continued to grow in the capital during the seventeenth century. Some glassblowers like Juan de Quiroz (Zárate Sánchez 2004:29),[68] and Blas Hernández (Fernández 1990:230, 258),[69] were still active in 1612 and 1617 respectively, and by this time both were considered masters of the trade. Juan Quiroz, in particular, is referred to as master glass cutter

[67] https://mediateca.inah.gob.mx/islandora_74/islandora/object/mapa%3A40.
[68] AHNCM, Protocolos, vol. 3359, f.50.
[69] AGN, Ordenanzas, vol. 3, f.38-39v.

(Maldonado Mares and Pineda Mendoza 1995:84).[70] New glassmakers came into the picture in the early decades of this century, including Juan Bautista Nieto in 1605 (Zárate Sánchez 2004:29),[71] glass master Francisco Prieto in 1617, and Juan de Mora, who had a workshop in the Barrio del Carmen (Fernández 1990:258).[72]

The flourishing of glass technology in the capital was linked to metallurgy, and more specifically to the process used for the separation of gold from silver (Peralta Rodríguez and Alvízar Rodríguez 2010). The silver from the mines in San Luis Potosí, usually came in the form of electrum, a natural alloy of gold and silver, and since 1575, the separation of these metals, known as *apartado* (gold-parting) was carried out in *oficinas* or workshops established near the silver mines and eventually in Mexico City (Elhuyar 1979 [1818]:47), although a Royal decree authorizing their establishment did not come until 1626. Part of the process required the use of glass retorts, as will be explained later. It seems that as soon as gold-parting was done in Mexico City, some local glassmakers began providing *apartadores* with retorts. The aforementioned Blas Hernández, Francisco Prieto, and Juan de Mora were all involved in the making of glass retorts used for gold parting in 1617 (Fernández 1990:230, 258).[73]

The number of glass artisans continued increasing in the 1620s, with seven new names appearing in the records (Appendix 3). Among them was Hernando Ramírez, a black glassmaker officer in his fifties working for Juan de Mora in 1628 (López Reyes 1985:5),[74] as well as some glass artisans specialized in the making of glass beads, such as Francisco Gutiérrez and Francisco Lara who in 1629 were *oficiales de cuentas de vidrio* (officer of glass beads).[75] The

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[70] AGN, Matrimonios, vol. 98. exp. 112, f. 299.
[71] AHNCM, Protocolos, vol. 3363, f. 988.
[72] AGN, Ordenanzas, vol.3, exp. 162, f.122.
[73] AGNM, Ordenanzas, vol.3, exp. 162, f.122.
[74] AGN, Matrimonios, vol 48, exp. 94, f.251v.
[75] The term *oficial* (officer) referred to a craftsman who had finished his period of apprenticeship as will be explained later in this chapter.

maker of glass beads and other small glass objects was sometimes called *vidriero del candil* or lampworker. This is because a common way to make beads is by reheating glass rods in the flame of a lamp until the glass is soft enough to shape it into beads or other small objects (Figure 42) (Cummings 2002:26-26).[76] This was the case of Pedro de Cárdenas, who in 1629 was an officer of lampworking living in Puente de San Lázaro (Martins Torres 2019b:128).[77] At least six more glassmakers appeared in the city during the 1630s (Appendix 3), including two glass lampworkers as well as a *tratante de vidrios* or glass merchant named Francisco Prieto (Pineda Mendoza and Zárate Sánchez 2005:83).[78]

Figure 42. Catalan tile depicting a lampworker, Museu Cau Ferrat, Sitges, 18th century (photo: Karime Castillo).

The 1640s brought more than ten glass artisans to the city, including a glassmaker from Seville, Francisco Leonardo de la Bandera who lived in Barrio de San Gregorio (Martins Torres 2019b:131),[79] as well as more glass artisans specialized in making glass beads and lampwork (Appendix 3). There is one new glass artisan documented in the city in 1652, Claudio Francisco Troncoso, who came from Burgundy, France, and was specialized in the making of ophthalmic

[76] Lampworking does not require a furnace.
[77] AGN, Matrimonios, vol. 113, exp.106, f. 269v-270.
[78] AHNCM, Protocolos, vol. 2481, f. 103.
[79] AGN, Matrimonios, vol. 126, exp.38, f. 116.

glasses "and other things of glass and tortoiseshell" (Martins Torres 2019b:132; Peralta Rodríguez 2004). Records of 1660s include three new glass artisans, one of whom, the Spanish Mateo Gómez, declared being both a glassmaker and a carpenter in 1664 (González Franco et al. 1994; 1986). The 1670s saw the first specialists in the making of *vidrieras* or glass windows,[80] which were usually commissioned for churches and some public buildings (Fernández 1994:83). Claudio Francisco and Mateo Chavez, both *maestros de hacer vidrieras* (masters of window glass), worked together to make the stained glass windows of the convent church Nuestra Señora de Valvanera in 1671 (Pineda Mendoza 2010:23),[81] and the glass master Claudio Francisco, who was paid five hundred pesos to make eight "Castilian" glass windows for the church of La Santísima Trinidad with *rejezuelos* or "wire grids" (Pineda Mendoza 2010:50).[82] In addition, at least four specialists in lampworking appear in the records of 1672, and the following year a specialist in the making ophthalmic glasses in El Empedradillo, whose name was Juan Bautista Tiburcio and had come from Burgundy sixteen years before (Martins Torres 2019b:128-132; Rubio Mañé 1966:216).

Notices of the Casa del Apartado, where gold-parting took place eventually under the auspices of the Crown, appear in the last quarter of the seventeenth century (Peralta Rodríguez and Alvízar Rodríguez 2010:8). The Casa del Apartado, which had glass furnaces and a team of glassworkers, was established in the northern limit of the first *traza* on a street that in the sixteenth century was called *Calle de agua que va al monasterio de Santo Domingo*[83] in the *barrio* or neighborhood of Cotolco. The street was later renamed Calle del Apartado (Peralta Rodríguez and Alvízar Rodríguez 2010:7; Ulloa 1999:55). The glass artisans who worked there

[80] The term *vidriera* can also refer to stained-glass window.
[81] AHNCM, Protocolos, Libro 15, f. 258v-260; f.390.
[82] AHNCM, Protocolos, Libro 21, f. 314v-315.
[83] Waterway that leads to the Saint Dominic monastery (author's translation).

were specialized in the making of glass retorts, distillation containers that were indispensable for the gold-parting process, as will be explained later.

New glassmakers appear in the records of the city during the last two decades of the seventeenth century, including both masters and officials, as well as specialists in lampworking (Appendix 3). Among those worth mentioning are Pedro de Mora Esquivel, a fifty-years-old free *mulato* who attained the level of glass master (Martins Torres 2019b:133),[84] Diego de Ávila, a *mestizo* also in his fifties, who was an officer glassmaker in the *barrio de la Alameda*,[85] and Tomás de Lizarra, a glass artisan from San Sebastián, in Vizcaya, who was in the city in 1689 (Rubio Mañé 1966:90).

The number of glass artisans in Mexico City throughout the seventeenth century surpassed fifty[86] and new specialists were available including people who dedicated to make glass beads, ophthalmic glasses, and glass windows, as well as some who exclusively did lampworking, a specialty that did not require a furnace. This increase in glassmakers and the appearance of specialists reflects the growing demand for glass products as well as its importance in other industries, particularly gold parting. While most glass artisans identify themselves as Spanish, the historical records also include: a *mestizo*, two free *mulatos*, and a black glass officer. European glassmakers continued arriving in New Spain, coming from Seville, Burgundy, and Vizcaya, although it is possible that some of the new artisans appearing in the records may have also come from abroad. For this century, there is more information regarding where glass artisans lived, although the mentions of glass workshops are scant. Most

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[84] AGN, Matrimonios, vol. 166, exp.44, f. 1v.
[85] AGN, Matrimonios, vol. 138, exp.70, f. 11v.
[86] Peralta Rodríguez (2013: 5) reported 66. Martins Torres (2019a: 129) includes people with ambiguous titles such as an *oficial del candil* named Antonio de Espinosa, who could be a lampworker but could also make lamps in materials other than glass. Uncertain cases like this one are not considered here.

artisans lived on the east side of the city, predominantly in the *barrios* or neighborhoods of: La Trinidad, Santa Cruz, La Merced, San Pablo, and San Lazaro (Figure 43).[87] The few references to workshops are not specific, instead, the presence of one may be inferred when there is a mention of the place where an artisan worked, for instance, the black glassmaker Hernándo Ramírez was "a resident in the barrio del Carmen where he worked with the master Juan de Mora" (López Reyes 1985:5). Similar mentions refer to possible glass workshops in the *barrios* of Santa Cruz and la Merced; the Spaniard Josephe de León, officer of lampworking worked in the first one,[88] while glassmaker Juan Ponce worked and lived in the second.[89] There are no mentions of the barrio de San Juan, but the mestizo glass artisan Diego de Ávila lived in the *barrio* of La Alameda. The park Alameda was built in the 1590s in an area overlapping the *barrio* of San Juan (Zamacois 1856:13).

[87] At least two glass artisans lived in these barrios, but there are single mentions of other glassmakers living in particular streets. These can be consulted in Appendix 3.
[88] AGN, Matrimonios, vol. 183, exp.26, f.2v-3.
[89] AGN, Matrimonios, vol. 173, exp.30, f. 2.


Figure 43. View of Mexico City in 1628 showing areas where glassmakers lived (blue), relevant churches, the Acequia Real (magenta), and La Alameda (modified from Planta y Sitio de la Ciudad de México, Johannes Vingboons, ca. 1660 (Aguirre Botello 2018)[90]).

During the eighteenth century, the number of glass artisans in the capital city continued to increase. At least seven new glass artisans appear in the records between 1700 and 1720 (Appendix 3). Some glass masters like Jerónimo Jhirordi in 1704 and José Pavón in 1721, began to act as specialized appraisers to assess goods such as mirrors and windows (González Franco et al. 1994:419, 294; 1986:55). Worthy of mention is the Spanish Andrés Monroy, who had spent time in the Philippines returning to the city when he was twenty-five years old; it is unknown if

[90] http://mexicomaxico.org/Tenoch/TenochTrasmonte.htm#vingboons.

he worked as a glassmaker while he was in Manila but in 1706, being twenty-nine years old and back in Mexico City, he no longer practiced the craft.[91] Twelve more glass makers were in the city during the 1720s, some in areas far from the city center, like José Antonio Gómez de Villegas who reported owning a glass furnace in Mixcoac in 1726 (Martins Torres 2019b:129), and Nicolás de Santa Ana who lived in Xochimilco in 1729, although at that point he was no longer active.[92] The number of glass artisans continued to increase in the 1730s, with at least eight new names in the records (Appendix 3). One of them, the Spaniard Francisco Xavier Gómez, lived north in Tlalnepantla and reported being a *labrador de vidrios*, which may refer to a glass carver or cutter (Martins Torres 2019b:130). Another one, the free *pardo mestizo* Manuel Rivera had a debt in 1734 for having rented a house and furnace in Puente Colorado.[93] The latter is an interesting case because he did not have the title of master, yet rented a furnace. There are only three glassmakers in the records of the 1740s, but eight new artisans in the 1750s (Appendix 3). An interesting case is that of Jospeh Nicolás Rodríguez, a Spaniard administrator of the glass furnace in Puente Quebrado,[94] although it is unclear if he was a glass artisan himself.

During the second part of the eighteenth century the number of new artisans in the city diminished. From the 1760s there are records of only two new glass artisans, both Spanish, who shared the same last name: Vicente and Marcos Antonio Ladrón de Guevara. Only Vicente, who was older, had the title of glass master (López Reyes 1985:80).[95] At least three new glass makers appear in the records of the 1770s and three more in the 1780s (Appendix 3). We know that around this time glassmakers may have been providing glass panels for public city lamps. A

[91] AGN Matrimonios, vol. 96, exp.64, f. 306v.
[92] AGN Matrimonios, vol. 174, exp.33, f. 3.
[93] AGN, Tribunal Superior de Justicia, Procesos Civiles, caja 110, exp. 3879, f. 1-19.
[94] AGN, Matrimonios, vol. 109, exp.98, f. 414v.
[95] AGN, Matrimonios, vol. 66, exp. 25, f.130.

drawing of an embellished *farol* or lamp by Pedro Joseph Cortés, dating to 1777, presents the design of a series of street lamps that were to enlighten the road leading to the Holy Inquisition (Figure 44).[96] The design suggests the use of small flat glass panels, sixteen on each side, to protect the source of light.

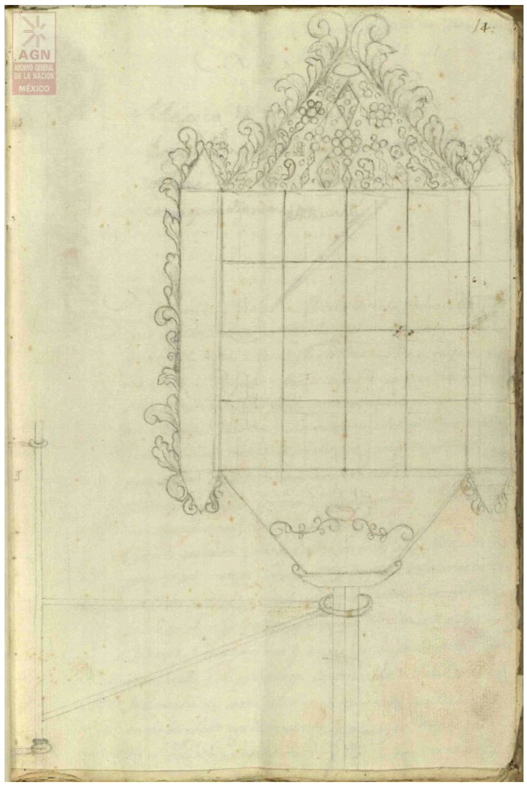

Figure 44. Drawing of the design of a street lamp for Mexico City, Pedro Jospeh Cortés, 1777 (AGN, Mapas, planos e ilustraciones, no. 4343; AGN, Ayuntamientos, vol. 107, exp. 1, f. 14).

After the apparent decline in the number of glassmakers, more than twenty new names of people involved in the glass business appear in the last decade of the eighteenth century. Rather than a sudden emergence of glass artisans in the city, the significant increase in the number of glassmakers documented in the 1790s may be a reflection of the census commissioned by the viceroy Revillagigedo of all the provinces of New Spain. Although half of it is lost, the available

[96] AGN, Ayuntamientos, vol. 107, exp. 1, f. 14.

records, shown in Figure 45, include the names of nine glass artisans that are not present in other sources (Miño Grijalva 2003).[97]

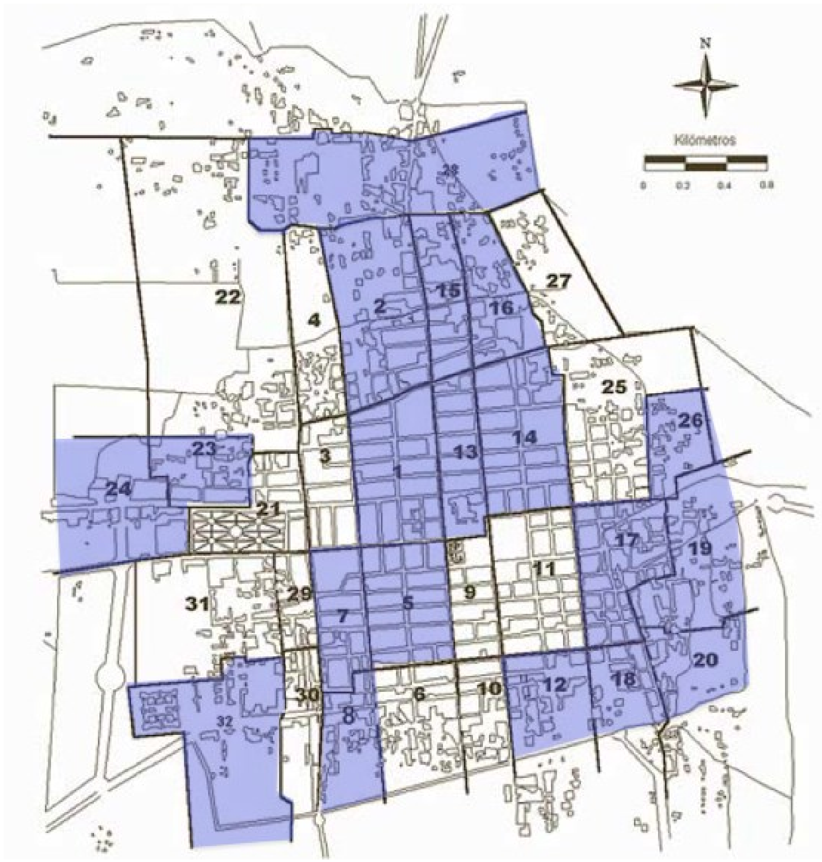


Figure 45. Map of Mexico City in 1790 showing the division in *cuarteles* used in the census ordered by Viceroy Revillagigedo. The areas in blue represent the sections with surviving documentation (modified from Miño Grijalva 2003).

Most of the glassmakers in the census declared to be Spanish, but there were two who were Indians, Anselmo Trinidad, who lived in Callejón del Vinagre and came from Chalco,[98] and Manuel Escobar y Llamas, who lived in Callejón del Olivo.[99] In addition, there was an indigenous apprentice in the glass furnace at the Casa del Apartado in the last years of the

[97] Peralta Rodríguez (2013: 12), who also studied the Census of Revillagigedo, has mapped the location of some of these glassmakers as well as other people who were potentially linked to the glass industry.
[98] Censo de Revillagigedo, "Cuartel" 19, f. 20.
[99] Censo de Revillagigedo, "Cuartel" 19, f. 46-47.

eighteenth century whose name was Miguel Gerónimo Ibarra.[100] Among the specialists mentioned in the records were Spanish José Antonio Ascáratea, a *graduador de vidrios y anteojos* who made ophthalmic glasses (López Reyes 1985),[101] and José Joaquín Serrano, a Spanish specialist in making mirrors with quicksilver.[102] There were also at least three people who had glass stores (Appendix 3), including glass merchant José Robles who had a store in the corner of street La Monterilla.[103]

The glass industry continued consolidating throughout the eighteenth century. The need for glass instruments for gold-parting was a major propeller of its growth, as will be discussed next. The number of glass artisans increased, with more than sixty new names in the records. Some of these artisans continued doing specialized work such as lampworking, the making of ophthalmic glasses, or using quicksilver to make mirrors, while some masters acted as appraisers. At the same time, there were people who identified themselves as administrators of a workshop or as owners of glass shops, who may or may have not been glassmakers themselves. The influx of foreign glassmakers seemed to have waned, but historical records do not always include the place of origin of the artisans, and it is likely that some foreign glassmakers continued to arrive. Glass artisans seem to have continued clustered in the east of the city, especially in the *barrios* of Santa Cruz and la Santísima Trinidad (Figure 46). However, a few of them had moved to other areas outside of the city including Xochimilco and Mixcoac to the south, and Tlalnepantla to the north, all of which were indigenous towns.

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[100] AGN, Casa de Moneda, vol. 31, exp. 16, fs. 187-188.
[101] AGN Matrimonios, vol. 82, exp. 99, f.434v-435.
[102] AGN Matrimonios, vol. 158, exp.26, f. 3-3v.
[103] AGN, Inquisición, Vol. 1368, exp. 18, f. 1-6.

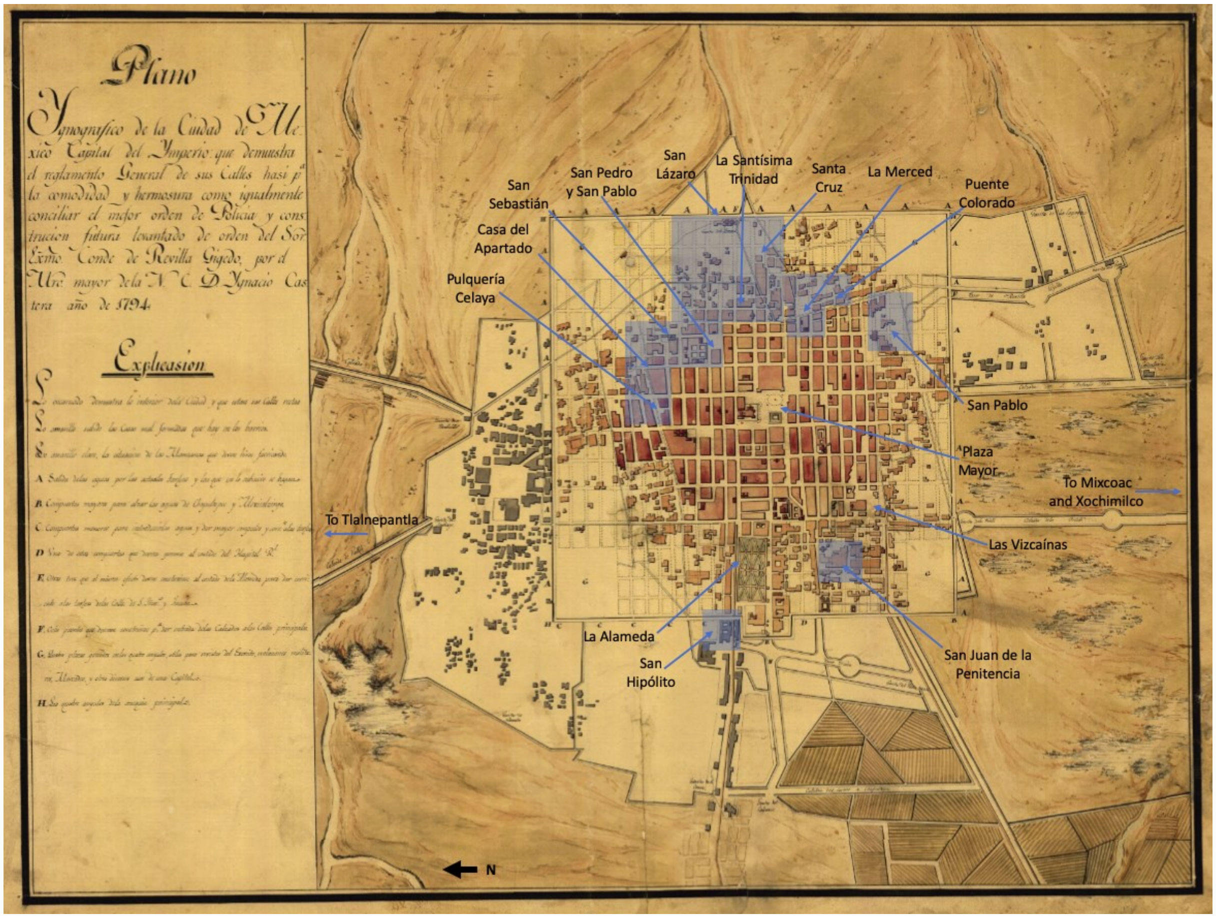


Figure 46. Map of Mexico City in the late eighteenth century showing the areas where glassmakers lived (blue), the relevant churches, and some landmarks (modified from Plano Ygonográfico de la Ciudad de México Capital del Ymperio, Ignacio Castera, 1794, Biblioteca Digital Mexicana A.C.).[104]

Towards the end of the colonial era, glassmakers continued to work and live in the east of the city. A census of indigenous workers from 1800[105] reports six indigenous glass artisans, some of whom worked in a glass furnace in the *barrio* of Santa Cruz and all lived in areas where glassmakers had traditionally lived such as Puente Colorado and La Santísima Trinidad. The glass workshop at the Casa del Apartado continued to be active, although it experienced

[104] http://bdmx.mx/documento/galeria/plano-ygnografico-ciudad-mexico.
[105] AGN, Padrones, Vol.103, f.144.

shortages of skilled artisans because many of them were recruited as soldiers[106] throughout the eleven years of war that led to the independence of Mexico.

### 6.3.1. Glass and gold parting

As mentioned above, gold-parting, which was of great interest to the Crown because of the economic value that both gold and silver represented, became an important propeller of the glass industry in the capital of New Spain. Until 1733, gold parting and the mint were managed independently. The official position of *apartador general* was created in 1655, and since the late seventeenth century, gold parting in Mexico City became centralized in the Casa del Apartado (Soria 1994:280). However, gold parting remained an independent endeavor until 1778, when the king ordered that it was annexed to the mint (Beltrán Martínez 1952:387, 389; González Gutiérrez 1995:62; Soria 1994:275).

Part of the gold parting process was done in glass retorts. Glass was the ideal material for the retorts because it provided a non-reactive container and its transparency facilitated the monitoring of the process (Peralta and Alvizar 2010:2; Ulloa 1999: 55). Gemelli Carreri, an Italian who travelled through New Spain in 1697 and visited the Casa del Apartado, described the process as follows:

> "…once the silver has been liquified it forms balls, which are placed in containers full with nitric acid so that they dissolve. The gold stays at the bottom like black gunpowder, and the liquid containing the silver is purred into glass containers that the Spaniards call cornamusas [retorts], the openings of which are joined together one against the other. When exposed to fire, the silver stays in one of the containers while the liquid passes to the other one." (Carreri 1955:158; translation by the author)

[106] *e.g.*, AGN, Casa de Moneda, vol. 81, exp. 3; AGN, Casa de Moneda, vol. 457, exp.21.

The glass *cornamusas* or retorts described by Carreri were probably similar to those illustrated by Antonio Alvarez Barba in the 1630s (Figure 47a), which were made of glazed ceramic and used to assay metals extracted from the mines of Potosí, in the Viceroyalty of Peru. Another example in which this type or containers are shown connected mouth-to-mouth as Carreri described them, can be found in the eighteenth-century chemistry treaty by Antoine Lavosier (Figure 47b).

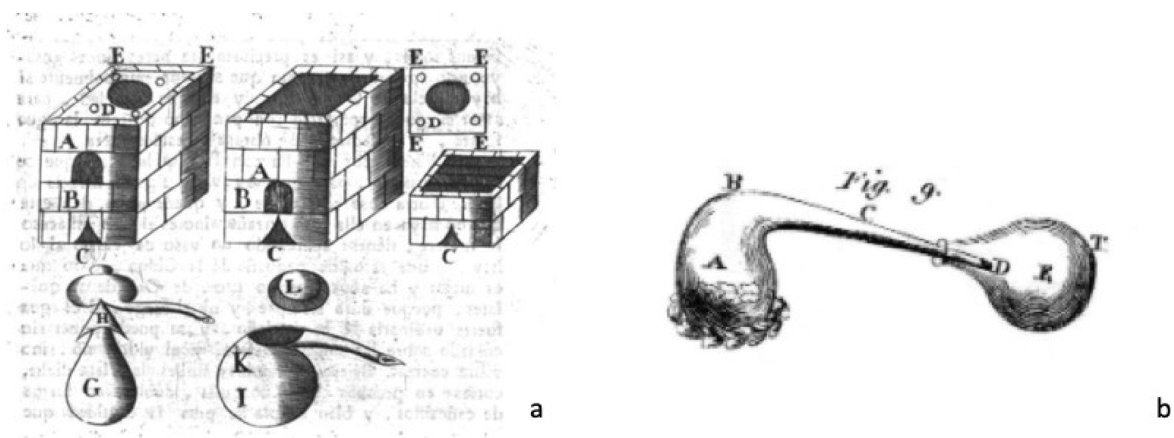


Figure 47. Illustrations of retorts: a) glazed ceramic retorts (H and I) placed on top of a glass urinal (G) as illustrated by Alvaro Alonso Barba (1817 [1640]:221); b) glass retorts used for distilling illustrated by Antoine Laurent de Lavoisier (1789:Plate III, Fig. 9).

We can better understand the need of a glass furnace in Casa del Apartado through a later description of the process written by Alexander von Humboldt (1966 [1822]), who arrived in México in 1803. Although the process may have undergone changes in the course of a century, it still involved the use of glass retorts. The description goes as follows:

> "The parting of gold and silver, reduced to granalla to multiply the points of contact, is done in glass retorts, placed on long lines over furnace grills measuring five to six meters long. These small furnaces are not heated with the same fire, instead, every two or three flasks form a separate furnace. The gold that is left at the bottom of the flask is turned into fifty-marc bars, while the silver nitrate is decomposed by the fire during the distillation in the retorts. This distillation through which the nitric acid is regained, is done also in a small furnace and takes 84 to 90 hours. To extract the silver reduced to crystals, it is necessary to break the retorts, because even though they could be conserved, if silver was precipitated through copper, another operation would be needed to

> decompose the copper nitrate, that would replace the silver one." (Humboldt 1966 [1822]:460)

Joel Poinsett, an American who served as a special envoy to Mexico between 1822 and 1823 and who also visited the gold parting house, described the use of glass retorts as follows:

> "In the center of another room was a large circular furnace, round the interior of which were placed glass retorts covered with luting and filled with the nitrous acid saturated with silver. The neck of each retort projected through the furnace, and was luted to that of another retort, placed on the outside of it. The acid is driven off by heat from the first, and is condensed in the second retort, leaving the silver strongly adhering to the glass. After removing as much of the metal as is practicable, the retorts are broken up and ground to an impalpable powder in stone mills. This is mingled with powdered *greta,* or lead ore, and the whole melted together and run into bars. These bars are afterwards put into large vessels made of powdered brick and cinders, which are so placed in the furnace that the lead, which melts at a lower temperature than silver, runs off, and leaves the silver in the vessel. There are several other rooms where the glass retorts are made, but I will spare you what I was obliged to listen to, and to see the whole process of making glass and blowing retorts." (Poinsett 1969:59)

Given that the retorts were broken to extract the metal, it makes sense that a glass furnace was one of the three workshops in Casa del Apartado, the other two being for the preparation of nitrous acid, and for the actual gold parting process (Humboldt 1966 [1822]:459). While the clean fragments of broken glass retorts could have been recycled (Martins Torres 2019a), Poinsett's description indicates that recycling may not have been significant. It should also be noted that powdered glass was sometimes used to prepare a mix used in gold parting containing also *caparrosa* (copper sulfates) and saltpeter, and it was sometimes added to silver to make it more malleable (Bargalló 1969:30-31).

The constant need of glass retorts at the Casa del Apartado explains how glassmaking and the resources needed to produce this material, became subject of the interest of the Crown. As Martins Torres (2019a:220-221) argues, glass production, as a craft complementary to gold parting, acquired high relevance for the Crown, which promoted the adoption of measures that would ensure its endurance and development.

### 6.4. Glass Production in Puebla

Puebla was also an important glass production center in colonial Mexico. It is unclear when exactly did the first glassmakers established themselves in the city, but as mentioned above, glassmaker Rodrigo de Espinosa, who had initially arrived in Mexico City, had moved to Puebla by 1542 (Icaza 1923:191). On May 11th of that year, after expressing his desire to establish a furnace in Puebla, Rodrigo de Espinosa was granted two plots of land to establish a glass workshop in the area around the Convent of Santo Domingo, on the way to the quarries. The grant stated that he would be received as a resident of the city after collecting his wife from Castile, and that he should be fully established in Puebla within a year and a half (Fernández 1990:226). Around this time, between 1540 and 1550, the viceroy demanded that all conquerors and settlers in New Spain officially announced their presence. Rodrigo Espinosa, presented himself as a glassmaker resident of Puebla who had been in New Spain for nine years. He also said he was married and had two children but was waiting for his wife to arrive, which suggests that he did not travel back to Spain to get her after receiving the grant of land. He finished by saying that he was poor, sick, and in need of assistance (Fernández 1990:44; Icaza 1923:191). Based on his declaration, his first years in the New World were a struggle. Whether he worked as a glassmaker in the capital or not, after nearly ten years in New Spain he was starting from scratch in a different city, he was struggling economically, he had health problems, and he was still waiting for his wife and children to join him. Nevertheless, he managed to get his glass furnace up and running within the expected timeframe and to make it very productive because a year and a half later, on December 10, 1543 the local authorities restricted him from obtaining wood from the surrounding area because the substantial amounts his craft required were causing deforestation (Fernández 1990:46, 227; Romero de Terreros 1951:132). Despite such restrictions, glassmaking began to flourish in Puebla.

Although Mexico City might have been the place of arrival of the first glassmakers, the records of the capital until the 1550s do not provide many clues regarding the establishment of glass workshops or the arrival of more glassmakers. The fact that Rodrigo de Espinoza decided to move to Puebla and start from zero after nine years in New Spain is noteworthy. Had he had a successful glass workshop in Mexico City, he probably would not have moved unless he wanted to expand his business, and if that was the case he would not have been struggling economically. A letter by Gonzalo Diez de Vargas to the King of Spain suggests, in fact, that until *ca.* 1547 glass was only made in Puebla. In the letter he mentioned that only in Puebla could anyone find a glass furnace and glassmakers; he believed that this was because it was possible to find the raw materials needed as well as enough fuel to feed the furnaces. His letter provides us with a vague glimpse of the glass that was made in the city, as he specified that three types of glass, based on its color, were made: crystalline white (colorless), blue, and green. He also mentions that both Spaniards and locals acquired the glass from Puebla, and that it was sent also to Guatemala and Peru (Fernández 1990:227; Romero de Terreros 1951:131-132; 1923:175-176). Fernández (1990:53) suggests that glass from Puebla was also sent to Puerto Rico as part of the everyday objects used by the Spaniards who managed different aspects of the *situado*, the funding destined to the construction of forts and the expenses related to the royal army and navy as well as the administration of the territories of the viceroyalty in the early Colonial period. Although there are no records of other glassmakers arriving in Puebla during the sixteenth century, it seems clear that by the end of the century, the glass industry was firmly established in Puebla.

The seventeenth century saw an increase in the number of glassmakers in Puebla. The *Alcabala* records of Puebla, which registered the payment of the *Alcabala* tax payed annually by the head of each household in the city, provide us with some of their names as well as the place where they lived. The first mention of a glass artisan in the Alcabala records dates to 1612 and corresponds to Diego López del Huerto, who lived in Calle de Sant Josephe and remained active until at least 1620, although he later moved to Calle del Carmen (Appendix 4).[107] Glassmaker Pedro Sánchez appears in the records of 1622 living in the street leading to the *descalzos*,[108] while glass artisan Jerónimo Gómez shows in 1627 living in Calle del Carmen.[109] Glassmaker Pedro Sánchez del Huerto, who probably is the same as the one above,[110] moved to Calle de San Miguel in 1629.[111] Two new glass artisans appear in the 1630s, Antonio Cortés, who specialized in the making of glass beads and lived in Calle del Señor San Joseph,[112] and Juan Navarro who lived in Calle de la Audiencia.[113]

Although new glassmakers were working in the city, it seems like their number remained low. Thomas Gage, a Dominican Friar from England who traveled in Mexico and Guatemala between 1625 and 1637, when describing the city of Puebla and the product made there said: "The felts likewise that are made are the best of all the country. There is also a glass house,[114]

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[107] AHMP, Alcabalas, Vol. 3, 1627-35, fs. 18, 34.
[108] AHMP, Alcabalas, Vol. 3, 1627-35, f. 229, 253; *descalzos* probably refers to the convent of the Discalced Franciscans.
[109] AHMP, Alcabalas, Vol. 2, 1612-1627, f. 18, 39v, 62, 97v, 115v,130v.
[110] The records are not always consistent in terms of providing the full name of the individuals, but it is safe to consider that they represent the same person even when one last name is omitted.
[111] AHMP, Alcabalas, Vol. 2, 1612-1627, f. 58v, 93v, 112.
[112] AHMP, Alcabalas, Vol. 2, 1612-1627, f. 95.
[113] AHMP, Alcabalas, Vol. 2, 1612-1627, f. 120v, 150v.
[114] The Oxford English Dictionary defines glass house as the building or works where glass is made.

which is there a rarity, none other being as yet known in those parts" (Gage 1969:50). This trend seems to have continued throughout the first half of the seventeenth century. There is only one new glass artisan in the 1640s, a lampworker named Diego Becerra (Toussaint 1974:146), and no new glassmakers reported in the 1650s. From the 1660s there are records of another artisan named Juan Gómez de Villegas who had the peculiarity of being a master of both glassmaking and pottery.[115]

Although the number of glass artisans in Puebla appears small, this may be a reflection of the historical documents revised so far, which does not include the parochial records, so the number could be larger. But the glass industry in Puebla was undoubtedly important and well regarded in New Spain. Proof of this can be found in the fact that in 1679 the viceroy demanded 200 glass grenades (Figure 48), made specifically in Puebla to be sent to Veracruz and shipped to the presidio in Santiago de Cuba. Two glass masters presented their bids: Antonio Díaz and Alonso Pardo, with the last one winning the commission at the price of three *reales* each and promising to have them ready within six days.[116] This was not the only time such a commission was requested by the viceroy. In 1684 he once more requested glass grenades to be made in Puebla and sent to Veracruz, except this time he demanded 1000 of them. Alonso Pardo bid for the commission again, but it was won by master glassmaker Alonso Gómez at the price of two and a half *reales* each, and promising to have them ready within twelve days. The fact that the viceroy demanded that the glass grenades be made in Puebla, despite the fact that there were probably more glassmakers active in Mexico City at the time is significant. This could indicate that the glass made in Puebla was deemed of better quality than that of the capital, but it could

[115] AGN, General de Parte, vol. 11, exp. 42, f. 48-52.
[116] AHMP, Tomo 152, Legajo 1517, f.99v.

also simply mean that it was cheaper or that the products could be made faster. Regardless of the reasons, these commissions highlight the importance of Puebla as a glass production center.

Figure 48. Example of glass grenades from the mid-eighteenth century excavated at the site of the Dominican monastery in Freiburg im Breisgau, Germany (https://commons.wikimedia.org/wiki/File:French_Glass_hand_grenades_from_1740.jpg).

Glassmakers Juan de Portes and his son Alonso de Portes, were probably also active in Puebla during the mid-seventeenth century. We know of them because of Fray Francisco Portes, who professed in San Francisco de Puebla in 1686 and his records indicate he came from a family of glass artisans (Martins Torres 2019b:133; Morales 2016:1691). Two more glassmakers were working in Puebla at the end of the seventeenth century, both involved in projects for churches: Juan del Río Gómez, who has both a glassmaker and a carpenter and participated in the construction of the Capilla del Rosario in the convent of Santo Domingo in 1687 (Castro Morales 1963:319; Pizarro Gómez 1997:73); and Juan de Armijo Villalobos, who was part of the contract for one of the altarpieces in the oratory of San Felipe Neri, in the Templo de la Concordia in 1695 (Castro Morales 1963:422; Martins Torres 2019b:133).

We can thus see that after Rodrigo de Espinosa established a successful glass furnace in Puebla in the mid-sixteenth century, the industry began to grow. By the 1630s there were at least two glassmakers specialized in the making of glass beads, while some others were skilled in other crafts like carpentry and pottery. The glassmakers lived in the north and east of the city, close to the San Francisco river (Figure 49). The quality of the glass products made in this city seems to have high, considering that they were sent as far away as Peru and that the viceroy demanded special commissions exclusively from the glass workshops in Puebla. Its good quality was also recognized by foreign visitors. Agustín de Vetancourt (1971 [1698]:47), when describing the city of Puebla in 1698, mentioned that the ceramics, glass, soap, and knives made in Puebla were amongst the best in New Spain, and that the glass, while not as fine, was similar to Venetian glass.

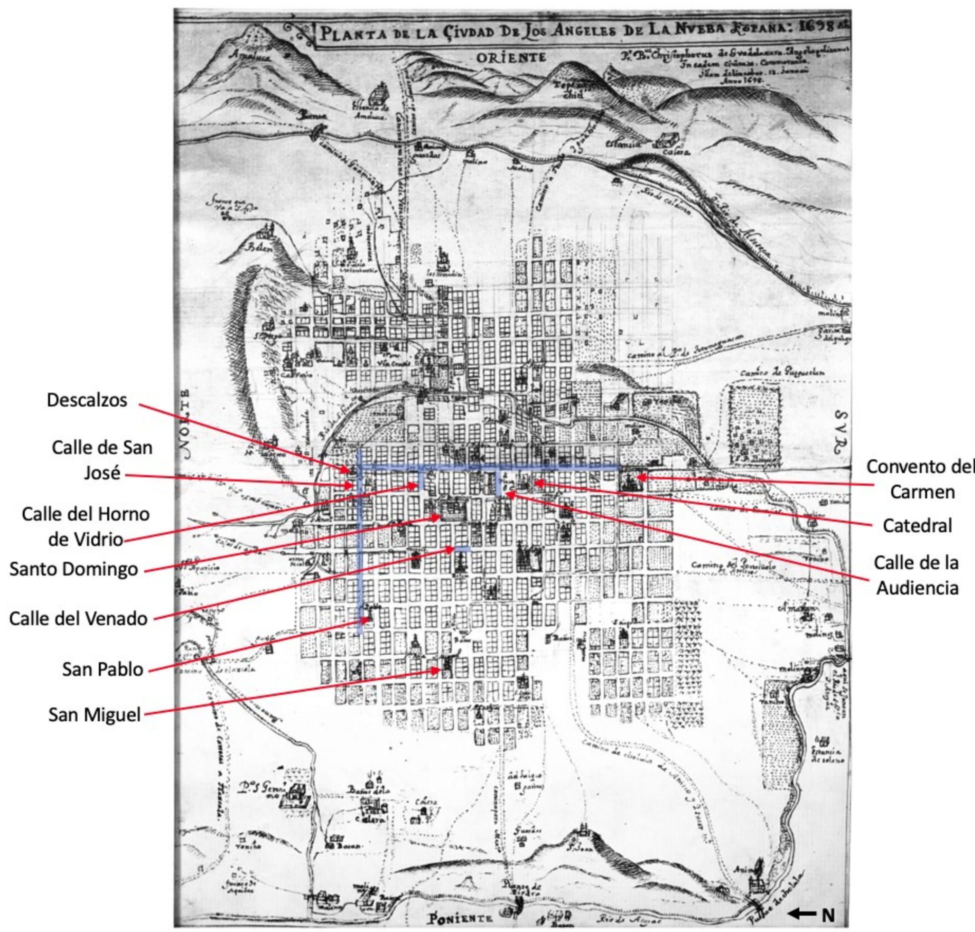


Figure 49. Map of Puebla showing the streets where glassmakers lived (in blue) and relevant churches (modified from Plano de la ciudad de Puebla de los Ángeles de la Nueva España by Cristobal de Guadalajara, 1698).[117]

[117] https://www.fotosdepuebla.org/mapas/jpg/1698a.jpg.

Glass production continued in Puebla in the eighteenth century with the advent of more specialized artisans and the emergence of important families of glassmakers. The glass furnace of Juan Gómez de Villegas in the Calle del Venado seems to have been active in 1712 but ceased functioning by 1724 (Leicht 1934:459). In the 1720s, there were glass artisans in Puebla who specialized in the making of stained glass windows such as Miguel Maldonado, who made the windows for church of Nuestra Señora de la Concepción (González Franco et al. 1994:249). Antonio Franco had a glass furnace in 1719. His assistant, Francisco Xavier de la Fuente, lived in the *barrio* of San Lázaro,[118] although it is unknown if the furnace was also located there. In 1722 the city also had an expert in mirrors and crystal named Antonio de Quiñones, but it is unclear if he was a glassmaker or just an appraiser (González Franco et al. 1994:249; Toussaint 1974:146). A glassmaker with the name Luis Pardo was active in 1720 (Fernández 1990:259) and a few years later, in 1723, Antonio Pardo established a furnace in front of the fence of the Santa Teresa convent; this street eventually became known as Calle del Horno del Vidrio (today 10 Oriente) (Cordero y Torres 1965b:221; Leicht 1934:188; Toussaint 1974:146). These glassmakers began a family business that was to last until the early nineteenth century. In 1744, Alonso Pardo took over the family glass business, followed by José Mariano Pardo in 1770 (Leicht 1934:189; Toussaint 1974:146). Another member of this family, Lorenzo Pardo, formed an association with Manuel de Lara to establish a glass furnace in 1772.[119] The last glassmaker of the Pardo family was Juan Pardo, who in 1786 had a furnace facing one of the side doors of the Santo Domingo Church, later known as Calle de Mariano Arista (today Av. 4 Poniente) (Cordero y Torres 1965b:221; Fernández 1990:261; Leicht 1934:21; Toussaint 1974:146).

[118] AGN Matrimonios, vol. 189, exp.19, f. 2.
[119] AGN, General de Parte, vol. 50, exp. 166, f. 155-155v.

The good reputation of the glass from Puebla continued during this century. A report presented to the Puebla City Council in 1746 by the Dominic friar Juan Villa Sánchez (1962 [1746]:38), for instance, claims that the glass made in Puebla "has no equal in the viceregal territory, and its quality, while not as high as that of Venetian glass, is comparable to that of French glass in smoothness, cleanliness, and clarity, and exquisite pieces are made with it…". Villa Sánchez (1962 [1746]:38) also mentions that some portions of glass were sent out of the city but not in considerable quantities, and he attributes this to the few existing workshops and the fragility of the material, which made its transport difficult. But the records of shipments reported by Fernández (1994:86) speak otherwise. Within New Spain, sixteen dozens of glass from Puebla were sent to Tabasco and Campeche in 1756, and twenty-five dozens the following year. Shipments to the provinces in Venezuela are more impressive, 282 dozens of Pueblan glass were sent in 1756, and another 153 dozens in 1757.

Large shipments of glass from Puebla to Venezuela continued until at least 1770, when 159 dozen were sent (Fernández 1994:86, 89). The accolades continued as well. Fray Francisco de Ajofrin (1964:44-45), a Capuchin monk who travelled in New Spain between 1763 and 1767, commented that the craftsmen in Puebla were amongst the best in the viceroyalty, particularly those who made soap, fabrics, fire arms, pottery, and glass, and that the city could easily be called the Barcelona of the Americas. However, positive opinions were later contested. Francisco Javier de la Peña (1835:111), considered that the glass made in Puebla was of regular quality and could never have competed with European products, not because of a lack of skills, but because of differences in the available raw materials.

Writing at the end of the eighteenth century, Fernández de Echeverría y Veitia (1962 [1780]:167, 304), who had been major of Puebla, said that the glass workshops in the city produced good-quality glass objects, in all sizes, and of different types, including clean and transparent Venetian-like objects, and thin glass pieces similar to the ones from Germany, all of which were sent to other regions. He also noted that in 1764 the city tried to establish glass lampposts in the city, but the effort was short-lived because some people enjoyed throwing stones at them to break them. At this time, window glass was still a luxury. People in Puebla covered their windows and skylights with fine sheets of polished *tecali* stone which allowed light to pass through (Fernandez de Echeverria y Veitia 1962 [1780]:293).

Moreover, especial orders of particular glass products were still made to Pueblan glass workshops. An example of this is a request made in 1793 by the General Intendent of the Marine in Cuba of 1600 glass vials of different sizes to be made in Puebla. The vials were to be used to make 800 hourglasses of different sizes which, depending on the amount of sand they could hold, would serve to count one minute, half an hour, one hour, or two hours (Figure 50).[120] Hourglasses were important instruments for tracking time, particularly in ships. A letter to the viceroy from a commissary in the port of San Blas written in 1781, for example, explained the delay in the departure of the royal frigate Nuestra Señora de los Remedios, bound to Peru, because of the lack of hourglasses; the departure was only possible after a half-hour hourglass was found by chance in the coffer of one of the pilots.[121]

[120] AGN, Historia, vol. 425, exp.2, f. 95.
[121] AGN, Marina, vol. 52, exp. 48, fs. 200-202.


Figure 50. Models for glass vials for hourglasses to be made in Puebla. Legends from top to bottom: 200 glasses for 100 vials [hourglasses] of two hours; 200 glasses for 100 vials of one hour; 200 glasses for 100 vials of half-hour; 600 glasses for 300 vials of [one] minute (AGN, Mapas, planos e ilustraciones, no. 430; AGN, Historia, vol. 425, exp.2, f. 95).

The eighteenth century continued to see the growth of the glass industry in Puebla, although the number of artisans and specialists was always smaller than in the capital. Glass furnaces tended to remain in the same streets, north of the Cathedral, as in the previous centuries (Figure 51). Specialists in the making of windows, glass beads, and mirrors, were active in the city. Most of the documents do not specify the origin of the artisans, but it is safe to assume that most of them were of Spanish origin. Except for a French glassmaker who spent some time in the city in 1809, there are no other records of other European glassmakers in Puebla, although it is clear that both artisans and consumers were familiar with European glass, particularly from

Venice. Although the glass made in Puebla did not reach the standards of fine European glass, locals and foreigners alike considered it to be of good quality, a characteristic that persisted throughout the seventeenth and eighteenth centuries. Proof of the high quality of Pueblan glass, or at least of the importance of the city as a glass production center, are the large requests of glass grenades and hourglass vials. The rivalry between Mexico City and Puebla becomes evident in the late eighteenth-century writings of Fernández de Echeverría y Veitia (1962 [1780]:305), whom while recognizing the fact that artisans in the capital succeeded in producing glass, said their products looked unclean and very ordinary, which he attributed to the lower quality of the *tequesquite* used, meaning more of it was necessary. He thought that, for this reason, the glass from Mexico City was even more prone to a fast deterioration than the one from Puebla and that many people in the capital and throughout the whole realm would prefer to get their glass from Puebla.


Figure 51. Map of Puebla in 1754 showing the streets where glass workshops were located (in blue), and relevant landmarks (modified from Plano de la Ciudad de Puebla, José Mariano de Medina, 1754).[122]

Beginning the nineteenth century, Juan Pardo's workshop was still active but by 1814 it had ceased to function (Leicht 1934:21). Glassmaker Miguel Ignacio Rementería, had a workshop in 1806, that seems to have been located on Calle de Iglesias (today 3 Poniente) (Fernández 1990:260; Toussaint 1974:146). Idelfonso Silva, was another glass artisan who owned a glass furnace, as stated on the appraisal of his possessions made after his death in 1807.[123] A French glassmaker with the name Luis was in Puebla in 1809, although he does not seem to have lived in the city.[124] The glass industry seems to have continued throughout the war of Independence, because in 1822, just one year after Mexico became an independent nation,

[122] https://www.fotosdepuebla.org/mapas/jpg/plano-medina.jpg.
[123] AGN, Tribunal Superior de Justicia de la Ciudad de México, Documentos Notariales, Caja 310, Exp.50, f.
[124] AGN, Inquisición, vol. 1445, exp. 7, f. 23-24.

there were 36 glass artisans working in Puebla, including an eleven-year-old apprentice named Vicente Laso (Fernández 1990:261-262) (Appendix 4).

## 6.5. Organization of Production

Most of the crafts in New Spain were organized in guilds, formal associations of specialized artisans developed in medieval Europe, and everything seems to indicate that the glass artisans in New Spain were organized in the same way. The origins of the New Spain guild system can be traced back to the thirteenth century in Spain, a time when many Iberian cities were already inhabited by people specialized in a particular trade. By the sixteenth century each villa in Spain had a variety of craftsmen organized in guilds that shared general characteristics with other guilds in Europe but also showed regional variations. The organization of craftsmen into guilds benefited its members by protecting their rights and allowing them to maintain a monopoly of their craft. Each guild had specific work rules, followed certain quality control measures, and established set prices for their products (Carrera Stampa 1954:8; González Franco et al. 1994:33; Santiago Cruz 1960:9, 13-16).

The guilds in colonial Mexico were hierarchically organized. Every craftsman began as an apprentice at a young age, which varied depending on the craft. After the successful completion of the apprenticeship, the craftsman became an official, and usually they stayed to work in the same workshop where they had learned the craft. Officials were not allowed to accept work that was not accepted by the master of the workshop, nor were they allowed to work at their own houses. Experienced officials could then undergo an examination to be certified as a master. The highest authorities were the *veedores* and the *alcaldes*, whose duty was to oversee that workshops and stores met the requirements of the guild. In addition, guilds usually had people in charge of the its accountancy, including a treasurer and an *oidor de cuentas* or auditor. Each category encompassed a set of obligations and privileges. Apprentices, for instance, received instruction as well as tools, food, dress, and lodging. In return they offered their labor, obedience, and fidelity to the master they worked with (Carrera Stampa 1954:25-71; González Franco et al. 1994:37; Santiago Cruz 1960:27-40).

Any craftsman who had aspirations of becoming a master needed to have a degree of economic solvency that few people had. To acquire this category, artisans needed to have enough resources to establish a workshop or a shop of their own. Additionally, a tax known as *media anata* was imposed in 1631 to anyone who had obtained an examination letter or who had been appointed as *veedor* or supervisor of a guild. Cope (2004:423) mentions that highly qualified officers from many different guilds would have chosen not to take the exam of mastery for economic reasons and for having other obligations, such as a family to maintain. So the reality was that in most crafts and industries the majority of the craftsmen remained officers throughout their lives and thus the guild became a corporation that defended primarily the interests of its most privileged members (Cope 2004:422-423; González Franco et al. 1994:37).

Guilds were usually regulated by ordinances designed to protect both the craftsmen, and the customers who bought their products. As legislative documents, they covered the personal, technical, and administrative issues. The ordinances of craft guilds usually included a list of regulations regarding the manufacturing process in order to ensure certain quality standards. They also contained specifications regarding apprenticeship and the requirements to become a master, which served as a way to restrict their number in order to avoid the division of profits among many hands. The city council was in charge of monitoring compliance with the regulations in order to guarantee the quality, quantity, and price of the products (González

Franco et al. 1994:34). Guild ordinances usually excluded the non-Spanish population from participating, including Indians, *mestizos*, *mulatos*, and other *castas*.[125] This was particularly true for attaining the level of master, who in many instances was required to be an old Christian, free of *mala raza* (bad race), and Spanish on four sides. Indians and *castas* were not allowed to become apprentices, but they could be hired *obreros* or laborers. Black people could only be incorporated into a trade as slaves. The masters did not have any obligation to teach the trade to *obreros* or slaves, and they usually limited their training to the aspects in which they were expected to help, so marginalized workers could only learn the craft through observation (González Angulo 1979:148-149, 152).

To this date, no ordinances for a glass guild in New Spain have been found. The only ordinances relating to glassmaking are from 1596[126] and 1617[127] and they pertain to the collection of *barrilla*, the plant used as a flux to lower the melting point of the sand to make glass (Fernández 1990:58-60), but so far, historical research has not yielded a document that specifies regulations regarding technical aspects of glassmaking or glassworking.

Some authors (Martins Torres 2019a; Peralta Rodríguez 2013) have argued that glassmakers may have associated with other guilds. This was a common practice in Spain. The glassmakers of Catalonia, as previously mentioned, were initially part of the *gremio de vidrieros y esparteros*, or guild of glassmakers and basketmakers, before separating into an independent guild (Gudiol and Artiñano 1935:51-52). This paring makes sense when we consider the practice

[125] The *casta* system was an artificial hierarchical classification used to categorize people of mixed ethnicity in Spanish America that did not fall within the main categories of Spanish, indigenous, and black people (Carrera 2003: 36; Martínez 2008: 1).
[126] AGN, Reales Cédulas Duplicadas, vol. 3, exp. 161, fs. 120v-122.
[127] AGN, Ordenanzas, vol. 3, fs. 38-39v.

of covering up glass bottles, carafes, and other containers in basketry for protection and to facilitate their transport and handling (Figure 52).

Figure 52. Carafe lined with wicker, Museo de Artes Populares de Sevilla, Spain (photo: Karime Castillo).

The glassmakers in Madrid, on the other hand, were part of the guild of glass merchants, which included both glassmakers and potters (Gudiol and Artiñano 1935:70). This antecedent has been presented to support the idea that the glassmakers in Mexico were part of the guild of potters, and emphasize the existence of an artisan in 1660, Juan Gómez de Villegas, who held the title of master of both glassmaking and pottery,[128] to support the argument (Martins Torres 2019a; Peralta Rodríguez 2013). Although it is possible that glassmakers and potters were associated in some ways, the evidence available so far is not enough to assume that glassmakers were part of the very well-established guilds of potters of Mexico City or Puebla. The ordinances of both the Mexico City and Puebla guilds are extremely specific regarding technical aspects, such as what constitutes the finest grade of ceramic and how it should be decorated, as well as the specific amounts of tin and lead that the glaze of each one of the types should contain (Castillo Cárdenas 2007:227-232; Cervantes 1939:22-48).[129] None of the points in the ordinances

[128] AGN, General de Parte, vol. 11, exp. 42, f. 48-52.
[129] AHDF, Vol. 432a, f.61v-66v.

of either city refers to glassmaking in any way even though similar points could have been made regarding glass. For instance, the ordinances of potters specify the proportions of raw materials needed to make both the ceramic bodies and the glazes and are very specific regarding the characteristics of the different qualities of ceramics produced. Similar guidelines could have been offered for the production of glass of different qualities as well as regarding specific types of decoration, such as the use of *lattimo* to create decorative patterns. Moreover, the ordinances of potters of Puebla specify that the finest majolica should be made in imitation to Chinese porcelain (Cervantes 1939:29); something similar could have been said about fine glass imitating a specific kind of glass such as Venetian, Catalan, Castilian, or later Bohemian. In addition, while it is true that both technologies require kilns and use some of the same raw materials, each technology requires specific facilities, distinct types of kilns, and involve completely different techniques of manufacture, so the regulations would have been necessarily different.

This is not to say that there was no close interaction between these groups of craft specialists. Glassmakers required ceramic crucibles to prepare raw glass, which had to be replaced periodically. It is also possible that potters provided covers for the mouth of the furnace to keep the heat while not in use. Glass workshops, in turn, could have been places for majolica potters to acquire raw materials and colorants. However, for glassmaking, this kind of interdependence went far beyond. Glass artisans also needed iron tools to manipulate the glass, bricks to build the furnaces, heavy milling stones to grind raw materials, as well as baskets and wooden boxes to safely keep the finished products. In fact, the interdependence with metalworkers would have been just as crucial as that with potters because the iron tools needed to be replaced periodically. Glass artisans in Jalisco, for instance, need to replace the tips of the blowpipes, which are in direct contact with the molten glass, every one or two months, and they usually replace the jacks every four years, and more often in the case of less experienced artisans (Castillo Cárdenas 2016). The use of shared raw materials or the use of kilns are, thus, not sufficient reasons for forming a common guild, and we should also remember that in Catalonia, the initial glassmakers guild included the basketmakers, who used a completely different raw material and did not require kilns.

Nevertheless, there is still the fact that Juan Gómez de Villegas held the title of *Maestro mayor de loza y vidrio* (Senior master of ceramic and glass). According to Martins Torres (2019a:396-397), this Spanish artisan took advantage of a new system established by the viceroy that allowed the purchase of certain work positions, which allowed him to buy that particular title from the Real Hacienda (Senior master of ceramic and glass). He then moved from Mexico City to Puebla to work on both crafts. Juan Gómez de Villegas was not well received in Puebla by potters, nor glass artisans, neither of whom recognized his title. Eventually it was decided that his title would only allow him to make glass and fine ceramic (majolica), and that he was able to keep some of the perks of being a *maestro mayor*, such as employing unexamined officers.[130] However, there is no further documentary evidence of this artisan to evaluate if he succeeded in his attempts to produce both crafts, nor are any other artisans documented to have held a title pertaining to both crafts. Juan Gómez de Villegas appears to be an exceptional case. Considering that he did not practiced his craft in Mexico City as far as we know, and the rejection and resistance he faced by glassmakers and potters alike in Puebla, it seems unlikely that glassmakers and potters were part of the same guild.

Another aspect of the organization that could indicate that glassmaking was part of the guild system would be the existence of a *cofradía* of glassmakers. Religious *cofradías* were an

[130] AGN, Reales Cédulas Duplicadas, vol. 20, exp. 150, f. 92v-96v.

important aspect of the guild system because it was through them that guild members who were injured, sick, or too old to continue working could obtain assistance. *Cofradías* also provided for the widows of craft members (Carrera Stampa 1954:79). One of the few examples of a glass artisan who had a link with a religious institution is that of Felipe de Godoy, who in 1734 requested from the Archicofradía del Rosario, which was founded in the convent of Santo Domingo, the amount of 200 pesos of gold in *reales* that had been allotted to his wife, María Ana de Heredia, as part of her dowry for being an orphan at that *archicofradía* (González Franco et al. 1994:175). Although this *archicofradía* accommodated many *cofradías* and guilds during the colonial era (Acosta Sol 2012:17), it is unclear if glassmaking was one of them. In the case of Felipe de Godoy, the link may have existed only on the side of his wife and might have had nothing to do with the glass craft.

While there are no known historical documents indicating the existence of a *cofradía* of glassmakers in New Spain, glass artisans were still required to participate in the religious festivities of the community. An ordinance from 1572 related to the festivities in honor of Saint Peter demanded that all the masters, officers, and workers of the different trades, among which glassmakers were listed, contributed with harquebuses, corselets and *cotas* or face a fine and a number in days in prison according to their rank (Barrio Lorenzot 1920:264-265).

Just like in Spain, the guilds of colonial Mexico City were grouped in particular neighborhoods or quarters (González Franco et al. 1994:33). The Censo de Revillagigedo shows this pattern in its *cuarteles* or sections, providing long lists of inhabitants sharing the same occupation, one after the other. The glassmakers were not an exception. Most of them lived and worked in the east of the city, with one small concentration south of La Alameda, and another one in the area around the church of San Juan. It is also interesting to notice that, while there is some overlap between the potters and the glassmakers quarters, especially on the west of the Plaza Mayor, more potters dwelled on the northwest side of the capital, in the *barrio* of Santa María Cuepopan located north of La Alameda (Lister and Lister 1982:90). Glass artisans were in general more scattered, extending on a broader zone that went beyond the area occupied by the potters (Figure 53).


Figure 53. Detail of Plano General de la Ciudad de México by Diego García Conde (1793) showing the areas where glassmakers (blue) and potters (green) lived and worked (Trabulse et al. 2002).

Although the documentary evidence of a glassmakers' guild is lacking, the craft seems to have functioned as one in terms of organization of production. The records often refer to glassmakers as masters, officers, and to a lesser degree, apprentices, which suggests that the traditional hierarchy followed in craft guilds was also followed in glass workshops. However, few letters of apprenticeship of young glassmakers have been found so far. The scant documentation that could confirm the existence of a guild of glassmakers suggests that there was no officially established guild. Regardless, the internal hierarchy of workers typical of guilds existed and it continues to permeate the craft today.

Glassworking in Jalisco seems to follow the hierarchical organization established by the guild system. Young people begin learning the craft as apprentices and they ascend in position as they master the different parts of the process. Throughout their apprenticeship period they work mostly as helpers. Once they master the basics they can learn to blow glass and become officials when they acquire a level of proficiency. After many years of practice and once they have learned every single aspect of the craft they can become masters. A master needs to know all the stages of the process and can cover any position when there are absences in the workshop (Castillo Cárdenas 2016).

6.6. People in the Glass Industry

For most Spanish crafts, the guilds ensured that control of production stayed in the hands of the Spanish elite. Ordinances that specified the level in the hierarchy attainable for different population groups, and restrictions on who could become an apprentice were part of the strategies that helped maintain control of the industry in the hands of the Spanish. Whether there was a formal guild of glassmakers or not, the craft seems to have followed the general parameters of guilds in terms of organization of production. However, the glass sector seems to have allowed for a certain degree of flexibility in terms of who could attain each level in the workshop hierarchy.

Most glassmakers in both Mexico City and Puebla were Spanish, but participants in the craft included people of the different *castas* such as *mestizos, castizos,* free *pardos*, and free *multatos*, as well as indigenous, black, and enslaved people. The majority of glass artisans in the records did not use the specific title of master or officer and were referred to simply as *vidrieros* or glassmakers. This makes it difficult to evaluate how restrictive the craft was. Of those who had the title of master, all except for two of them were Spanish and one of these exceptions was the *mestizo* Juan Solis, master of lampworking and glassmaking.[131] This is not surprising considering most guilds restricted the title of master to Spaniards of "clean blood"[132] and old Christians (Carrera Stampa 1954:51), although in some cases, like the potter's guild of Mexico City, it was also accessible to *mestizos* (Castillo Cárdenas 2007:28). However, there was a glass master in Mexico City, active in 1681, who was a *mulato* free of captivity, fifty-year-old Pedro de Mora Esquivel.[133] His case is noteworthy because most guilds demanded a letter of *limpieza de sangre* (clean blood) to grant permission to present the exam that could allow them to become masters of their trade (Carrera Stampa 1954:51). This could indicate that either there was no guild that regulated access to the higher positions in glassmaking, or that the regulations were not as restrictive as for other guilds.

Those glass artisans who identified themselves as officers, were also mostly Spanish and a couple were *mestizos*. But there were also a black glass officer named Hernando Ramírez, who lived and worked in the barrio del Carmen in Mexico City around 1628, when he was fifty-four, although he originally came from Veracruz (López Reyes 1985:5).[134] [135] In addition, there was a

[131] AGN, Matrimonios, vol. 72, exp. 5, f. 51.
[132] For a Spaniard to have "clean blood" or *limpieza de sangre* meant that the person had a "clean" lineage without "stain" of black African, Moorish or Jewish blood (Carrera 2003: 2). This concept was transferred to the Americas and expanded to include indigenous people and the different *castas*.
[133] AGN, Matrimonios, vol. 166, exp.44, f. 1v.
[134] AGN, Matrimonios, vol. 48, exp. 94, f.251v.
[135] Martins Torres (2019a: 303-304) argues that Hernando Ramirez was in charge of a glass furnace owned by Juan de Mora located in Veracruz, in Barrio del Carmen, based on his testimony declaring that Manuel Sánchez, a black *criollo*, was free to marry (AGN, Matrimonios, vol. 48, exp. 94, f.251v). However, the researcher seems to have missed the fact that both Hernando Ramírez and Manuel Sánchez had moved to Mexico City and had lived there for six years at the time that the petition was made and the testimony was taken. While the testimony, transcribed in Appendix 5, may be open to some interpretation, there is no Barrio del Carmen in the port city of Veracruz, nor was there a convent or church of this designation in the port city in the seventeenth century or later in the colonial period (Malgrejo Vivanco 1960; Hernández Arana 2016), as there was in Mexico City. In addition, no records of

free *pardo* glass officer, Manuel Gómez, who was active in Mexico City in 1727 (Martins Torres 2019b:129),[136] and an indigenous officer at the glass furnace of the Casa del Apartado in 1816.[137]

Glassmakers with specialties such as lampworking, glass cutting, window, mirror, and ophthalmic glassmaking, and those associated with gold-parting, were all Spanish except for two specialist in the making of ophthalmic glass, Claudio Francisco Troncoso (Fernández 1990:258) and Juan Bautista Tiburcio (Rubio Mañé 1966:216) both from Burgundy, France, and the mestizo lampworker, Juan de Solis, mentioned above.

Of the glass artisans denominated simply as *vidrieros*, with no specific title or specialty, the overwhelming majority were once more Spanish. Indigenous people are the second group most widely represented, but their presence in the records as glassmakers only starts at the end of the eighteenth century, in the Census of 1790 with Anselmo Trinidad, a tributary Indian who lived in Callejón del Vinagre,[138] and Manuel Escobar y Llamas, an indigenous man living in Callejón del Olivo,[139] followed by six glassmakers registered in a census of indigenous artisans from 1800,[140] all of whom lived in Mexico City. There are no records of indigenous glassmakers in Puebla. Glassmakers from the *castas* included two *castizos*,[141] a *mestizo*,[142] a free *mulato*,[143] and a free *pardo mestizo*.[144]

glassmakers or glass workshops in Veracruz are known to this date. It is possible that Hernando Ramirez learned glassmaking upon arriving in Mexico City and developed his skills in the six years he had lived in the capital. According to glass artisans in Jalisco, it takes about two years for a glass artisan to learn about 80% of the craft, and between five and seven years to become proficient (Castillo Cárdenas 2016: 34).

136 AGN, Matrimonios, vol. 4, exp.1, f. 4-4v.

137 AGN, Casa de Moneda, vol. 31, exp. 16, fs 187-188.

138 Censo de Revillagigedo, "Cuartel" 20, f. 20.

139 Censo de Revillagigedo, "Cuartel" 32, fs. 46-47.

140 AGN, Padrones, Vol.103, f.144-144v.

141 AGN Matrimonios, vol. 140, exp.23, f. 6-6v; AGN Matrimonios, vol. 1, exp.7, f. 36-36v.

142 AGN Matrimonios, vol. 145, exp.43, f. 3v.

143 AGN Matrimonios, vol. 36, exp.57, f. 215v.

144 AGN, Tribunal Superior de Justicia, Procesos Civiles, caja 110, exp. 3879, f. 1-19.

Glass workshops producing at a relatively large scale also benefit from having *arqueros* or workers in charge of the tempering kiln, and *atizadores*, people in charge of feeding wood to the furnace.[145] Historical records indicate that there were also glass furnace managers, like the Spaniard José Nicolás Rodríguez, who probably oversaw the whole process;[146] *veedores* or supervisors such as Juan de Espinosa, named *veedor* of the lampworkers of Mexico City in 1640 probably because he was an expert on his field (Bejarano 1910:45; Martins Torres 2019a:421-422); and appraisers, like Antonio de Quiñones who was an expert on mirrors and crystal in Puebla (Toussaint 1974:146). Moreover, glass workshops needed the collaboration of other workers to function effectively. These include people to collect the raw materials, loggers to provide the fuel, *arrieros* or muleteers to transport raw materials and finished products on the backs of mules, as well as glass merchants to distribute them. In the Census of Revillagigedo there are entries of *tratantes en leña* or wood dealers such as José Manuel Fuentes, a thrity-two-year-old mestizo, native of Mexico living in section 20.[147] Muleteers lived all over the city and are often mentioned in the census. Peralta Rodriguez (2013:5-6, 10) also mentions *areneros*, who may have been suppliers of sand, as well as a *barillero* registered in Mexico City in 1790, the mestizo José la Cruz,[148] who may have been in charge of the processing of the *barrilla* plant ashes. A few years later, in 1796, there was another *barillero*, the mestizo Antonio Marzelino.[149] The important role played by the suppliers of raw materials and fuel is further discussed later in this chapter.

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[145] Peralta Rodríguez (2013) also includes *horneros* or kiln workers, however, the term can be associated to other crafts other than glassmaking, for instance, pottery, lime preparation, brick making, and bakery. Given that ambiguity, *horneros* that are not explicitly related to a glass furnace were not considered here.
[146] José Nicolás Rodríguez, for instance, was the manager of a glass furnace in Puente Quebrado, Mexico City, in 1752 (AGN Matrimonios, vol. 109, exp.98, f. 414v).
[147] Censo de Revillagigedo, "Cuartel" 20, f. 10.
[148] Censo de Revillagigedo, "Cuartel" 5, f. 38v.
[149] AGN, Matrimonios, vol. 123, exp. 56, fs. 257-264.

Women are rarely mentioned in the historical records related to the glass industry, which is not surprising because glassworking is a predominately male craft. In the workshops of Jalisco and Puebla, for instance, the substantial majority of glass artisans are men. But this does not mean that that women are not involved in the industry. Women are owners of glass workshops, they are at the forefront of stores, and many of them work in the packing and/or management areas, but only one or two in some workshops work as artisans manipulating the glass (Castillo Cárdenas 2016:33). Similarly, women were not excluded nor absent in the New Spanish glass industry. In eighteenth-century Mexico City, there were two women who owned glass furnaces, Micaela Gerónima Becerra[150] and Marcia Luisa de Arana (Martins Torres 2019a:403).[151]

On June 8th, 1728 Doña Micaela Gerónima Becerra bought a glass furnace from Don Miguel de Iseto, a merchant from Mexico City. The workshop was located in the street that went from the Convent Nuestra Señora de la Merced to the college of San Pablo, below the Puente del Ataud (bridge of the coffin).[152] The following day, Don Miguel sold her a thirty-three-year-old *mulato* slave, color *prieto cocho* named Juan Joseph for 200 pesos.[153] One year later, Doña Micaela presented a lawsuit to the Real Audiencia against Don Miguel de Iseto regarding the transfer of the aforementioned glass furnace. The reason behind the lawsuit lies on the fact that Doña Micaela believed that she was deceived about the real value of the furnace at the time of the purchase. She recounts that she owned a *tienda de algodones* (cotton shop)[154] located in the street of Santo Domingo that she wanted to sell. Don Miguel de Iseto, knowing she was a poor

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[150] AGN, Civil, vol. 350, exp. 2.
[151] AGN, Civil, vol. 10, exp. 27.
[152] AGN, Civil, vol. 350, exp. 2, f. 1. It should be mentioned that the lower half of the volume presents water damage which rendered many parts illegible.
[153] AGN, Civil, vol. 350, exp. 2, fs. 3-3v.
[154] The items in the store included different types of cotton, thread, and yarn, but also incense, combs, *petates* (reed mats), *chiquihuites* (baskets), parchment, *palo de Campeche* (a natural dye), various pigments (*e.g.*, carmine, ochre, vermilion), gold, silver, tin, plaster, urinals, and pins among other things. The large diversity and nature of the items suggest it was a haberdashery (AGN, Civil, vol. 350, exp. 2. fs. 79-80).

woman, proposed to transfer the glass furnace to her. The day of the transaction, Don Miguel brought with him a glass master, Antonio Franco, and between the two of them valuated the property. Although Doña Micaela was present, she said that Miguel de Iseto and Antonio Franco did the appraisal without her intervention because she could not understand anything discussed.[155] After the visit, Miguel de Iseto told her that the price was one thousand five hundred pesos, but that she should rest assured because they would adjust the amount she had to pay taking into account what she had in her store (the cotton store she intended to sell). She ended up paying one thousand and sixty pesos. However, she complained that once she spent time in the furnace and heard other opinions she realized that she had been deceived about its real value, leaving her destitute.[156] The process became more complicated when in March of 1729 Doña Micaela tried to take the matter to trial because, although legitimately married to Don Joseph Cordero, she did not live with her husband, so she was asked to give power of attorney to Francisco Manuel Chirlin, procurator of the Real Audiencia, so that he could represent her in trial. Her request was granted after three witnesses were interviewed regarding the absence of her husband.[157] The litigation led to three inventories of the glass workshop by different specialists. In 1732, the deed was declared null and the Real Audiencia ordered that the workshop be seized

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[155] Martins Torres (2019 a: 401-202) suggests that Doña Micaela Gerónima Becerra may have been a glassmaker herself. However, considering Doña Micaela's comment on not understanding anything said during the visit to the furnace and a declaration later made by Antonio Franco saying that she called him because she was afraid of being deceived (AGN, Civil, vol. 350, exp. 2, fs. 1, 36v-37), both indicate that she was not familiar with glass workshops. The researcher argues that she could have acted as the master of the furnace because her husband was not around, assuming the privilege granted by guilds to widows to take over the workshops if the husband died. But her husband was not dead and his occupation is unknown. While she probably managed the workshop, it is unlikely that she actually worked in the furnace handling the glass herself as a glass master would do. Before buying the furnace, she owned a haberdashery so she had experience in management and commerce but nothing indicates that she was a glass artisan.

[156] AGN, Civil, vol. 350, exp. 2, fs. 1, 36-37v (there are issues with the numbering of these pages because, after folio 35, three consecutive folio are numbered 38, however the page numbers continue in correct order afterward).

[157] AGN, Civil, vol. 350, exp. 2, fs. 10-12 (unfortunately, the water damage of the document obscures the reasons behind her husband's absence).

and auctioned;[158] the following year she demanded to be compensated for the grievances she suffered.[159] The quarrel continued until 1735 when Don Miguel was required to pay four hundred pesos to Doña Micaela.[160]

Some years later, in 1766, Marcia Luisa de Arana, owner of a glass workshop in Puente Colorado, found herself in trouble for not delivering an order of white glass bottles that Beltrán Sopeña had requested and payed in advanced, causing him to lose his entire production of liquor for lack of appropriate storage containers (Martins Torres 2019a).

These examples show the direct involvement of women in the colonial glass industry. Although it is unlikely that they worked in the furnaces manipulating the glass themselves, both Micaela Gerónima Becerra and Marcia Luisa de Arana demonstrate that, despite the deep patriarchy prevalent in colonial Mexico and even within a male-dominated craft such as glassmaking, women could be both owners and managers of glass furnaces. Doña Gerónima's persistence on pursuing justice when she suspected to have been deceived, also highlights the agency of women, even though she had to give power of attorney to a male procurator in order to have her voice heard.

Martins Torres (2019a:395) considers that women played another important role in the colonial glass industry as agents of formation of strategic networks between glassworkers through matrimonial alliances. Her analysis of glass artisan families revealed, for instance, that several women with the last name Solís were married to glassmakers from different European and New Spanish families, outnumbering the two male glass artisans with this last name,

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[158] AGN, Civil, vol. 350, exp. 2, fs. 105-107.
[159] AGN, Civil, vol. 350, exp. 2, f. 241.
[160] AGN, Civil, vol. 350, exp. 2, f. 263.

Melchor Solís[161] and Juan de Solís,[162] both in Mexico City and active in 1646 and 1718, respectively. This brings to the fore the role that women played in establishing and consolidating networks between different glassmakers, which would have promoted their growth and success.

The litigation between Doña Micaela and Miguel de Iseto also brings to light the participation of another sector of the population: enslaved people. Being considered part of the workshop, Juan Joseph got caught in the middle of the quarrel. When the Real Audiencia ordered the auction of the furnace, he raised his voice. In March of 1732 a notary wrote on his behalf, and using the first person, that given that he had already been appraised in a hundred and twenty-five pesos, he should not have to wait for the glass furnace to be auctioned and should be sold immediately because he was already in his mid-fifties and having served as officer in the furnace he had lost his health, so a long wait would make it difficult for him to find a new master.[163] He was sold the following month for a hundred pesos.[164] The case of Juan Joseph indicates that slaves had a certain degree of agency. It also demonstrates that slaves were active participants in the glass industry, being allowed to learn the craft and serve as officers.

The majority of the glass artisans in both Mexico City and Puebla worked in privately owned workshops, however Mexico City also had the glass workshops at the Casa del Apartado which was administered by colonial authorities. The following sections will describe both types of production centers.

[161] AGN Matrimonios, vol. 172, exp. 93, f. 1v.
[162] AGN, Matrimonios, vol. 72, exp. 5, f. 51.
[163] AGN, Civil, vol. 350, exp. 2, f.108.
[164] AGN, Civil, vol. 350, exp. 2, f.111.

### 6.7. The Private Glass Workshop

It remains unclear how many glass workshops operated in Mexico City and Puebla at different stages in the colonial period. The records mention several masters, and artisans who achieved that level earned the right to own a furnace and a store. But establishing a glass furnace was an expensive pursuit, requiring the rent or acquisition of a suitable space, building a furnace and a tempering kiln, acquiring complete sets of tools, buying the raw materials to make the glass and fuel to fire the furnace and tempering furnace, as well as for hiring workers, all of this in addition to the payment of the *media anata* tax. Glass workshops require a number of people to work properly. Given the limited amount of time a glassworker has to work a piece before it cools down and stiffens, there is a pressing need in glass workshops for other people who can take care of other parts of the production process, such as monitoring the tempering furnace, or feeding the kilns with wood.

Not much is known about the earliest glass workshops in New Spain, but curiously, Doña Michaela's fight for justice provides us with a glimpse into what private glass workshops were like in eighteenth-century Mexico City, the people who worked in them, and how they operated. On January 12th 1729 Doña Micaela demanded an appraisal of the furnace and tools that were transferred to her.[165] Four months later, on May 21st 1729, Don Miguel de Iseto lodged an appeal against the requested valuation and, after going back and forth counterclaiming each other, Doña Micaela finally got the appraisal she demanded. On September 12th 1729, Colonel Juan Gutierrez Rubin de Zelis, alderman and ordinary mayor of the city, ordered the valuation to take place, and he specified that there should be appraisers that are expert not only in glass, but also in carpentry, masonry, and metalwork.[166] This would be the first of three inventories made throughout the

[165] AGN, Civil, vol. 350, exp. 2, f. 137v.
[166] AGN, Civil, vol. 350, exp. 2, f. 149, 171-171v.

litigation process, the second one being performed in 1730,[167] and the third one in 1731.[168] These inventories illustrate the things regularly found in a working glass furnace and provide clues about the technology used for glassmaking and the objects made. As an example, the translated transcription of the inventory made in 1731 is provided below:[169]

> "Memory of the tools, walls, and huts needed for a glass furnace, with the manufactured work and materials that exist for its production and what was found of everything in existence is the following
>
> Firstly, a firing furnace with six crucibles and a tempering furnace in ninety pesos everything
> And two new crucibles that are outside in ten pesos
> And four burners to place window glass in twelve pesos
> And a large table and two small ones of white stone from Pachuca in fifteen pesos
> And a fritting furnace in twenty-five pesos
> And a crucible of fine glass that is in the large furnace in sixteen pesos
> And four other crucibles of ordinary glass that are in said furnace in twelve pesos each, adding up to forty-eight pesos
> One stone mill with a *macho* [beast] that powers it in thirty pesos
> And two lose milling stones in eight pesos
> And one mortared portion of fine worked glass that is outside the furnace in sixteen pesos
> And thirty-five loads of *tequesquite*, each load at one real, [adding up to] four pesos and three reales
> And eight loads of sand to work the glass at three pesos the load, add up to twenty-four pesos
> And of cakes of fine glass, one hundred and thirty four *arrobas*[170] each they add up to one hundred pesos and four reales
> And thirty arrobas of ordinary [glass] cakes in paste at four reales each they add up to fifteen pesos
> And twenty-five arrobas of barilla cakes in paste at one peso each they add up to twenty-five pesos
> And forty six arrobas of barilla in the rough at three reales each they add up to seventeen pesos and two reales
> And nine hat boxes in which worked glass is stored made of ordinary wood at a peso each they add up to nine pesos
> And thirty-two molds of ordinary wood for glass, all of them in four pesos and four reales
> And two boxes for window glass in said wood at one peso and four reales
> And one bench and a table of said wood with its key, all in three pesos

[167] AGN, Civil, vol. 350, exp. 2, f. 195.
[168] AGN, Civil, vol. 350, exp. 2, f. 235.
[169] The water damage in the inventory of 1730 obliterated half of the document and it seems to be incomplete. For a transcription of the inventory made in 1729 see Martins Torres (2019a: 626-628).
[170] An *arroba* was a measuring unit equivalent to approximately 12.5 litters although it varied by region.

And seven old sieves for sifting in seven reales
And one thousand four hundred sixty six dozens counted of worked glass of different qualities, each dozen holding a prefixed price of five reales, they add up to nine hundred twenty two pesos and four reales.
And eighty three dozens more of said articles that were worked from the ordinary glass batches that were in the aforementioned furnace at the same price adding up to fifty one pesos and seven reales since the fourth day of January seven hundred thirty-two until the fifth day of said month and year that the valuation of everything noted and more expressed in this memory was finished
And fifty loads of wood at seven reales the load add up to forty-three pesos and six reales
Nicolas Rueda, master locksmith appraised the iron tools of the furnace which are as follows:
Firstly a spoon of seven pesos
And a *corvo* (provably a curved instrument) in seven pesos
And another old spook in four pesos
And a two-pronged fork in two pesos
And a *lettadon* in two pesos
And a copper shovel with its iron end for window glass in ten pesos
And three iron blowpipes a little longer than one *vara*[171] in two pesos
And five pontil rods to work glass in five [pesos]
And one hook, a blade, and a *rodadillo* to work window glass, all in two pesos and two reales
And three copper marvers in three pesos
And three pairs of bellows, three pairs of jacks and a pair of scissors all in four pesos
And one bronze mold of quarter barrel in six pesos
And another small one [mold] in twelve reales
And another [mold] of *cacahuate*[172] in eight pesos
And another used [mold] for small jars/vials in six pesos
And another four [molds] of right canal in in twelve pesos
And another [mold] of iron in two pesos
And another two openwork [molds] of iron in two pesos
And an axe in one peso
And two buckets and a vat with its iron hoops in five pesos and six reales
And a large copper pan in thirty five pesos
Juan Mathias de Arcos, master carpenter, appraised the wooden tools that were found in the following way:
Firstly three chairs of ordinary working wood in twelve reales
And a large shed that covers the furnace in eightly pesos
And another [shed] for storage in twenty-five pesos
And anther [shed] for the mill in ten pesos
And another [shed] for the horse stable in five pesos
And a sieving trough in six pesos
And another large one [trough] in four pesos
And another of said [trough] in four pesos

[171] A *vara* was a measuring unit equivalent to three feet (in the old Spanish measuring system) or 0.84 m in length.
[172] The term *cacahuate* (peanut) probably refers here to a specific shape or design.

And another two small ones [troughs] in five pesos
And three good trays in three pesos and seven old ones in one peso that add up to four pesos
And three baskets in six reales
And four *chiquihuites*[173] of frit in six pesos
And nine empty *chiquihuites* in four pesos
Alfonso de Contreras, master *alarife*,[174] appraised the adobe walls and storage rooms in thirty-five pesos
And Juan de Rivera, merchandise broker, appraised Juan Joseph Gomes, black slave belonging to the furnace who must be around fifty-five years old,[175] in one hundred twenty-five pesos
All the parts sum up and make up the quantity of one thousand nine hundred thirty-five pesos and seven reales total
Francisco Morales [rubric]
For the Depositary
Manuel Gomez [rubric]
Named by the Depository
Nicolas de Rueda [rubric]
Juan Mathias Arcos [rubric]
Manuel Gomes [rubric]
Juan de Ribera [rubric]" [176]

In terms of facilities and furniture the inventory reflects what would be expected in a standard glassblowing workshop: a furnace in a shed, a tempering furnace, a fritting kiln, a storage shed, an animal-powered stone mill protected by a shed, and another shed for the horse stable. There were also numerous crucibles to contain the glass, stone tables, copper marvers, wooden chairs, a table, and a bench, as well as spare grinding stones for the mill. In addition, this workshop had *hornillas*[177] for stained glass windows, which indicates that flat glass was also made in the premises. Notice that the inventory specifies an *horno encendido* or firing furnace. This is because glass furnaces are usually kept afire until it is time to replace them. This practice

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[173] *Chiquihuite* is a type of basket.
[174] *Alarife* is an old term used to refer to the construction foreman.
[175] It seems that this is the same enslaved person that Doña Micaela bought from Miguel de Iseto, the mulato Juan Joseph, but the use of different versions of the name as well as different designations of his skin color including black, *mulato*, *pardo*, and *pardo cocho* create confusion.
[176] AGN, Civil, vol. 350, exp. 2, fs.101-104v (translation by the author).
[177] *Hornillas* (burners) were used in stained glass window making to heat the glass to approximately 620° C in order to fix the colors applied (Brown and O'Connor 1991:60).

of constant firing is seen today in the traditional glass workshops of Jalisco and Puebla. Glass artisans explain that keeping the furnace afire is the most economical way to run them because it takes days to get them to the appropriate temperature as well as to get the glass molten. Those days represent a large expense in terms of fuel without any output of glass products (Castillo Cárdenas 2016:72).

Tools and other utensils listed include the basic toolkit for glassworking, that is blowing pipes, pontil rods, jacks to shape the glass, scissors to cut any extra glass, and buckets that would be filled with water to periodically cool the jacks. Wooden and iron molds of diverse shapes and sizes,[178] would have helped in the making of standardized products. The two-pronged fork, likely of large dimensions, is the instrument used to take finished products to the tempering furnace and also to arrange them inside. There are also instruments used to process raw materials such as sieving troughs of various sizes, iron spoons, probably large, which are used to mix the glass melt inside the furnace, a tub to cool down large instruments or to clean cullet, bellows to stoke the fire, and an axe to cut wood. Instruments used to make glass windows include a copper shovel, a *garabato*, a *paletilla*, a *rodadillo*, and a *corvo*. The list also contains two types of wooden storage boxes, one of which was specifically for window glass, as well as baskets of different kinds. The latter, served multiple uses. In the inventory, four *chiquihuites* are holding frit, but they could also serve to move things around the workshop. In a glass workshop in Mallorca cullet is kept in ceramic containers of large size with handles that, interestingly, imitate the shape and texture of baskets (Figure 54), perhaps a longer-lasting version of the baskets originally used.

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[178] Martins Torres (2019a: 625) suggests that some of the molds may have been for the making of beads.

Figure 54. Ceramic imitation of baskets holding cullet in a glass workshop in Mallorca, Spain (photo: Karime Castillo.

As for raw materials and fuel, the inventory mentions sand, two types of alkali: *barrilla* in the raw and in cakes, and *tequesquite*. There are also mentions of intermediate products such as ground glass, frit, and glass cakes (ingots) of both regular and fine glass, as well as several loads of wood to feed the furnaces. In addition, the inventory mentions thousands of finished glass products of different qualities.

The inventory tells us that the glass workshop of Doña Micaela produced both hollow ware and flat glass for stained glass windows. The presence of different types of molds not only facilitated and sped up the process but also allowed for standardized products to be manufactured. The mention of both raw materials and instruments to process them indicates that the workshop cooked its own glass and there are indications that glass of different qualities was made. The document also tells us that cooking the glass involved a two-part process: first a frit was made, which seems to have been stored in the form of cakes. These cakes were probably ground before the second step, in which the frit was melt into glass. As will be later discuss, additional raw materials and/or cullet may have been added in this second step. In addition, the inventory shows the extent of the investment that an aspiring glass master needed to make in order to establish their own glass workshop. Taking this into consideration, it is evident that few artisans would have had the means to open a workshop of their own.

The litigation process provides us with another set of documents that provides additional information on the functioning of glass workshops: the weekly expenses of the glass furnace between April 1730 and July 1732.[179] These reports provide information about the expenditures in raw materials (*tequesquite*, sand, lime, *barrilla*, colorants) and fuel (wood), as well as payments made to the workers (glass officers, *mozos* or young workers, *hornero* or furnace specialist, *velador* or night guard, and the slave), the food (*zacate*, a type of grass) for the animals that powered the mill which are also called *machos* or beasts, the food and horseshoes for the horses, and maintenance expenses. An example is transcribed and translated below:

> Furnace expenses [of December 2nd, 1731]
>
> For, 217 loads of wood at 7 reales the load
> For 27 reales for the making of a jar mold
> For 4 reales that I gave for 2 pounds of blue color
> For 12 loads of tequesquite at 1 real and a quarter the load, adding to 15 reales
> For 8 loads of sand for glassmaking at 3 pesos the load, adding to 24 pesos
> For 13 pesos and 17 that were paid to the [glassmaker] officers for what produced in the week
> For 4 pesos and 3 reales paid to the workers
> For 1 peso and 3 reales to the slave Juan
> For the [1] peso of *zacate* [grass] and water for the *macho* [animal that powered the mill][180]

The one item that is consistently mentioned in the reports almost every week is wood, evidently the fuel used in the glass furnace. The wood is recorded in *cargas de leña* (loads of firewood), with amounts varying from six to 64 *cargas* per week, although they usually fluctuate

[179] AGN, Civil, vol. 350, exp. 2, fs.106-190, 221-227. There are issues in the page numbering in this section. A consecutive order was followed regardless of the number on the folio.
[180] AGN, Civil, vol. 350, exp. 2, f. 169.

between 15 and 27. Each load was worth seven reales. Sometimes *canoas de leña* (canoes of wood) are mentioned, which were composed of several loads. One of the reports mentions: "For 2 canoes of wood that were bought that had 59 loads of firewood at 7 reales the load, it comes to 52 pesos and 6 reales".[181] Another measure was *manos de leña* (bundles of wood), which could refer to a smaller amount than a load if we take into account that some reports mention both: "For 11 loads and 12 bundles of firewood at one peso the load it comes to 11 pesos 1 real."[182] The reports also show an increase in the price of wood, from 7 reales in 1730 to 1 peso in 1732.[183]

*Tequesquite* is another item frequently listed. It was also measured in loads and it seems to have fluctuated in price, considering that it initially appears costing 1 real and a quarter but in 1732 it appears listed at a price of 1 real per load.[184] *Barrilla* is only mentioned once in the weekly reports: "for 180 arrobas of barilla at 2 ½ reales,"[185] but as mentioned above, it is present in the inventories.

Sand was also measured in loads, each one costing 26 reales, but it could also be charged by *viaje* or trip. A *viaje* probably referred to a lesser amount or a lower quality of sand because the price was only 3 reales per trip.[186] Occasionally, the reports specify *arena de pedernal* or flint sand, the price of which was significantly higher, each load costing 3 pesos·[187] She also once bought "twelve loads of marble sand with 159 arrobas and 18 pounds at 3 pesos the load."[188] Considering that the price was the same, it is possible that the terms flint and marble were used

[181] AGN, Civil, vol. 350, exp. 2, f. 168.
[182] AGN, Civil, vol. 350, exp. 2, f. 173.
[183] AGN, Civil, vol. 350, exp. 2, f. 183.
[184] AGN, Civil, vol. 350, exp. 2, f. 180.
[185] AGN, Civil, vol. 350, exp. 2, f. 118.
[186] AGN, Civil, vol. 350, exp. 2, f. 122.
[187] AGN, Civil, vol. 350, exp. 2, f. 123.
[188] AGN, Civil, vol. 350, exp. 2, f. 182.

indistinctively. In addition, she twice she bought *pedernal molido* or ground flint, which was even more expensive at 23 pesos the load.[189]

Colorants for the glass were bought frequently. In some cases the reports simply mention color, which was bought by the pound, but sometimes they specified the color. The most frequently purchased was blue, but purple was acquired on one occasion: "For 8 reales of purple color for the fine one."[190] Since the reports do not always specify the quantity, it is difficult to assess the value of the each color. The price of a pound of blue color was 1 peso 3 or 4 reales.[191] In addition, one of the reports mentions the purchase of "2 reales of *caspa de fierro* [iron scraps] for black."[192] Its purpose is not specified, but it might have been used to make black or very dark green glass.

Different types of baskets called *chiquihuites* and *tompiate* were other articles that recurrently appear in the weekly expenses. These were usually bought by the dozen, unless they were large pieces which were sold individually.[193] On two occasions, it was specified that the *chiquihuites* were for the frit,[194] while on three reports it was mentioned that *tompiate* was for *pasteladura*.[195] There is also a purchase of two large *canastos* (baskets) to keep the glass.[196]

In the weekly reports we can also get an idea of the differences in the salaries of the workers. On April 2nd 1730, an officer received 3 pesos 4 reales, and a second one 3 pesos 5 reales; an *atizador,* who was in charge of feeding the furnace with fuel, was paid 2 pesos 1½ reales; the night guardian got paid 7 reales; while Juan, the slave working as *arquero* in the

[189] AGN, Civil, vol. 350, exp. 2, f. 131, 153.
[190] AGN, Civil, vol. 350, exp. 2, f. 130.
[191] AGN, Civil, vol. 350, exp. 2, f. 137.
[192] AGN, Civil, vol. 350, exp. 2, f. 152.
[193] AGN, Civil, vol. 350, exp. 2, f. 124
[194] AGN, Civil, vol. 350, exp. 2, f. 129, 136.
[195] AGN, Civil, vol. 350, exp. 2, f.122, 166, 183.
[196] AGN, Civil, vol. 350, exp. 2, f. 121.

tempering furnace received only 1½ real for his food.[197] The space where the workshop was located seems to have been rented, because there are records of payments done to a landlord for the amount of 12 pesos.[198] It is interesting that the slave worked as *arquero* in charge of the tempering kiln because it is a position that entails great responsibility. The tempering furnace needs to be kept at a temperature of around 400ºC in order to allow the glass to cool down at a slow pace. At a higher temperature, there is a risk of deformation in the finished objects, while at a lower temperature, the vessels will cool down too quickly and break. At the glass workshops in Guadalajara, Jalisco the *arquero* throws into the tempering furnace a piece of paper and counts the seconds it takes it to ignite. At the ideal temperature, it will take three seconds for the paper to catch on fire. Today's *arqueros* also say that the arrangement of the glass objects inside the tempering furnace is also important. If objects are not well arranged, there is a higher risk of breakage (Castillo Cárdenas 2016).

It is possible that the amount paid to the workers of the furnace depended on the amount of products made, because the salaries can vary from week to week. For example, on April 8th, 1730 the officers got paid 4 pesos 7 reales and 4 pesos 4½ reales each. On this date, two *mozos* were paid 2 ½ pesos each per day; while Juan received 1 peso 2½ reales.[199] Then on the week of April 22nd 1730, glass officer Manuel received only 1 peso 4 reales, while Juan received 1 peso 2½ reales for his food.[200]

Maintenance expenses inform us about the type of structures in the workshop. On April 22nd 1730 an order of 600 *clavos de tejamanil* or roof nails were bought to repair the ceilings, as

[197] AGN, Civil, vol. 350, exp. 2, f. 250
[198] AGN, Civil, vol. 350, exp. 2, f. 267
[199] AGN, Civil, vol. 350, exp. 2, f. 251.
[200] AGN, Civil, vol. 350, exp. 2, f. 252.

well as 250 bricks, 14½ loads of clay and sand, 14 loads of lime, and 600 adobes.[201] These expenses indicate the workshop had a tiled roof, and that it had brick or adobe walls. Brick could also have been used to make the furnaces. In fact, one of the records mentions "large bricks for the kiln where window glass is made," as well as the "2 pesos 5 reales that cost fixing that kiln."[202] Listed are also the salaries of two officers and one *peon* or laborer who fixed the roofs (5 reales daily for the officers and 3 reales for the *peon*), as well as a mason who got paid 6 reales per day. A master carpenter who placed the axis of the mill got paid 3 pesos, and a master blacksmith got paid for the products he made: 13 pesos for a metal spoon, and 8 pesos to fix another one.[203]

Some of the objects mentioned in the reports provide us clues of certain processes taking place in the furnace. For instance, we can tell that the furnace mouths were covered with clay "doors" probably similar to the ones used in Jalisco today (Figure 55). On July 12th 1730, a purchase of "one trip of clay to cover the mouths of the furnace" was registered.[204] Since they were buying clay, this suggests that they were making the furnace covers or "doors" in the workshop. These ceramic covers provide a small opening to gather glass on the blowpipe and to anneal small blown objects, and they can be removed to provide a larger opening to anneal larger vessels. The records also indicate that both wooden and metal molds were used contemporaneously because the expense records register the purchase of both kinds of molds. A wooden mold, for instance, was bought for 3 *reales* on June 7th 1730.[205]

[201] AGN, Civil, vol. 350, exp. 2, f. 252v
[202] AGN, Civil, vol. 350, exp. 2, f. 358.
[203] AGN, Civil, vol. 350, exp. 2, f. 252v.
[204] AGN, Civil, vol. 350, exp. 2, f. 365.
[205] AGN, Civil, vol. 350, exp. 2, f. 361.


Figure 55. Ceramic “doors” or covers at the feet of a glass furnace in Jalisco (photo: Karime Castillo).

Most private glass furnaces of the time would have had similar facilities and would have needed the same kind of instruments and furniture as those listed in the inventories of the furnace purchased by Doña Micaela. The weekly records offer us a glimpse into the activities that took place in these workshops and the earnings of different workers. It is clear that both wood and raw materials needed to be replenished frequently, which indicates that reliable procurement of these materials was crucial for glass workshops. I will discuss this issue further below, but before that, it is important to discuss the glass workshop at the Casa del Apartado, which eventually became sponsored by the Crown.

## 6.8. The Glass Workshop at the Casa del Apartado

As mentioned above, an important glass workshop existed in the Casa del Apartado. While the industrial development of the colonies was not fostered by the Crown, which preferred that overseas territories remained dependent on the metropolis, the need for a constant supply of glass retorts for gold parting meant that the success of the glass industry became of direct interest to the Crown.

Peralta and Alvizar (2010) have provided important details regarding the organization of the glass workshop, specifying that one of the four *guarda vistas* or guardians who looked after the site was specifically assigned to guard and keep track of the expenses of the glass furnace and workshop, which was staffed by thirteen *peones* or workers, and several glass officers; there was also a night guard who had to make sure that the *atizadores*, that is, people in charge of feeding firewood to the furnace, did not fall asleep (Fonseca and Urrutia 1845:291-294), which indicates that the furnace was firing day and night.

The glass facilities at the Casa del Apartado included two workshops with glass furnaces communicated by an entryway and covered with tiled roofs. One of the workshops, dedicated to the preparation of raw glass, had two furnaces, one for glass and one for its first benefit, which probably referred to frit, as well as a grate. The second workshop, devoted to glassworking, had two glass furnaces and two tempering furnaces. In addition, there were two patios and several storage rooms where the raw materials and finished products were kept including: one for *barrilla*, two for glass, four for retorts, as well as one for saltpeter, and one for soil. All of these facilities were located on the lower level of the two-story building (Figure 56).[206] The two last storage rooms deserve an explanation. Although the historical records do not indicate the use of saltpeter, this material can be used in glassmaking, and it is also possible that *tequesquite* was stored in this room. Saltpeter was, however, needed for some of the mixtures prepared that were prepared as part of the gold parting process, which explains the presence of a designated place for its storage. It is unclear why there was a storage room for soil, but it may have been the place where sand and/or *tequesquite* was stored.

[206] AGN, Mapas, planos e ilustraciones, no. 502; AGN, Casa de Moneda, vol. 388, exp. 5, fs. 62-63.

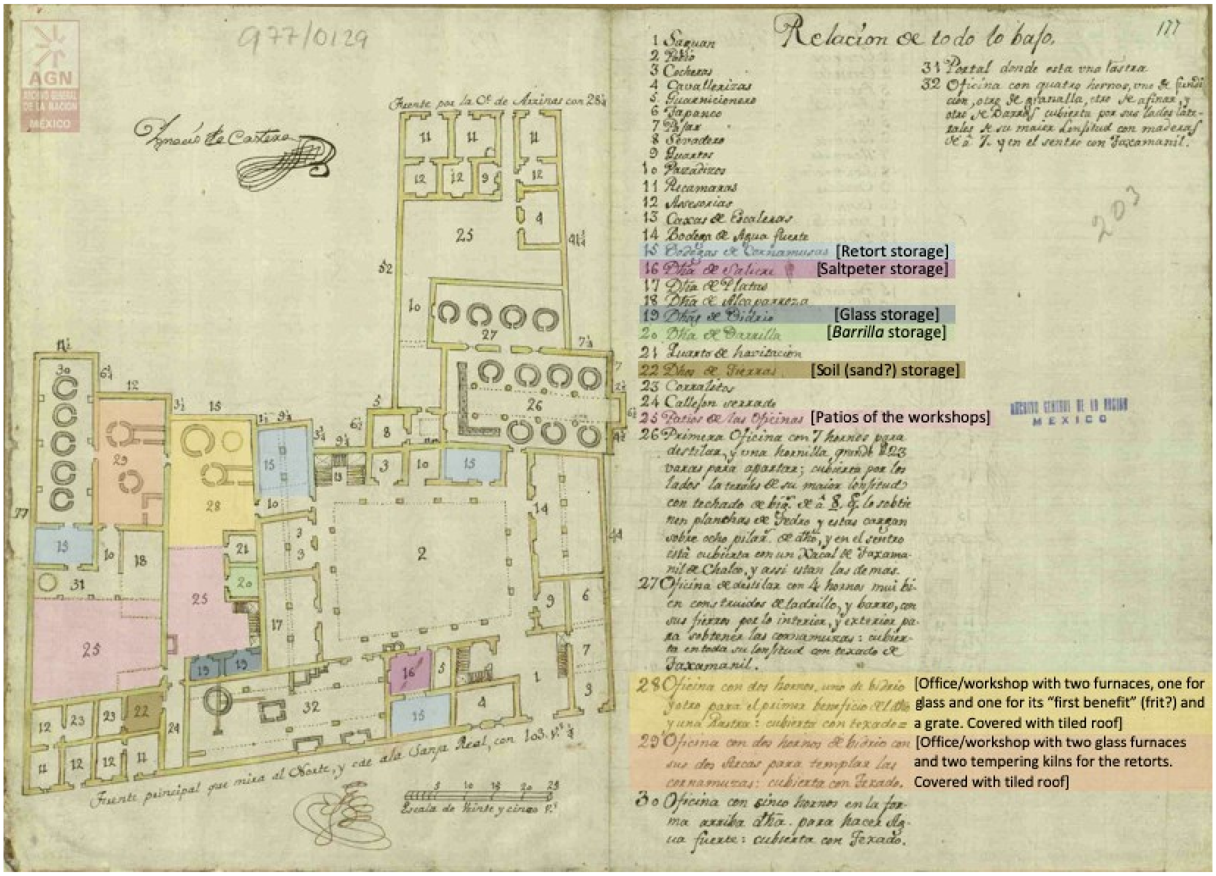

Figure 56. Floorplan of the lower level of the Casa del Apartado showing the glass furnaces, patios, and storage spaces for raw materials related to glassmaking (modified from Ignacio de Castrera, Relación de todo lo bajo, 1779; AGN, Mapas, planos e ilustraciones, no. 502; AGN, Casa de Moneda, vol. 388, exp. 5, fs. 60v-61).

Additional information on the facilities can be found in a floorplan accompanying a report on the situation of the glass workshops also made in 1779 (Figure 57). The plan specified that the firewood, which came in through a particular entryway, was laid down to dry on the workshops patio, and later stored under the roofed portals of the patio. The different appearance of this floorplan could be due to a schematization of the space or to modifications in the facilities. The Casa del Apartado was later expanded with the acquisition of two adjacent plots of land in 1795, one of which would house a new glass furnace because one of the existing ones had deteriorated (Peralta Rodríguez and Alvízar Rodríguez 2010:9-10).

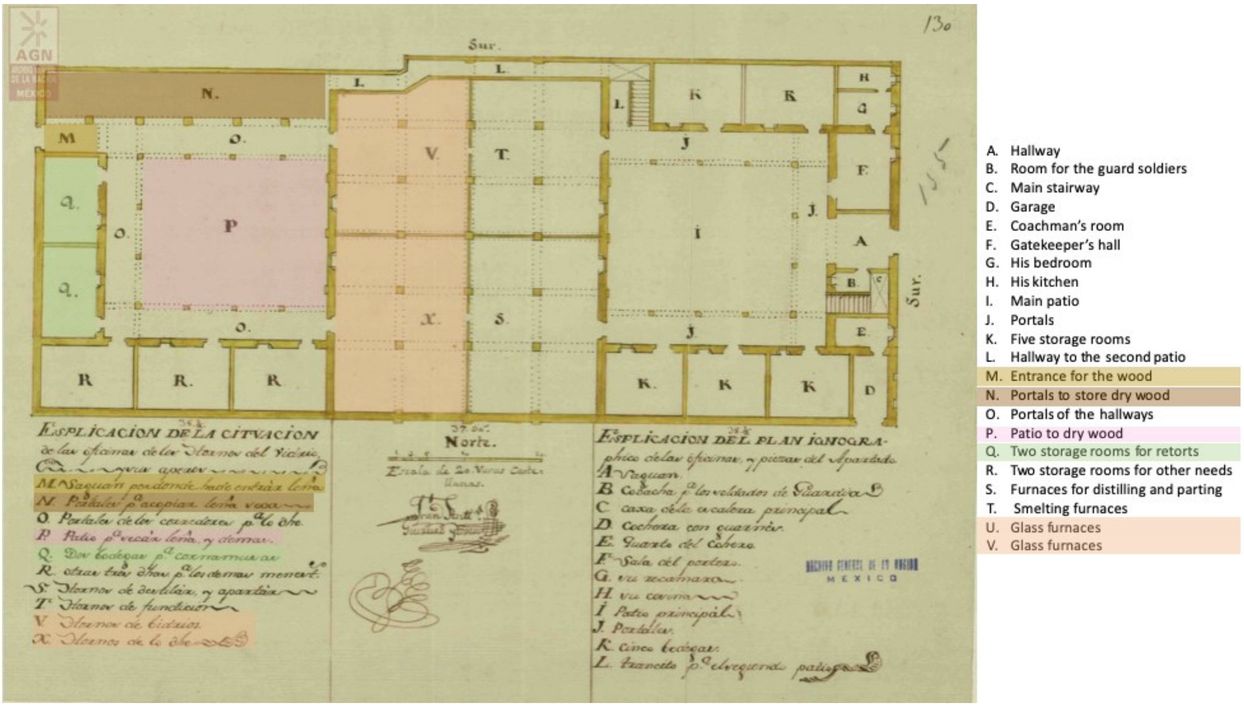

Figure 57. Plan of the workshops in the Casa del Apartado. (modified from Francisco Antonio Guerrero y Torres, Explicación de las oficinas de los hornos de vidrio, 1779; AGN, Mapas, planos e ilustraciones, no. 139; AGN, Correspondencia de Virreyes, 1ª serie, vol. 116, exp. 4, f. 155v).

The glass officers at the Casa del Apartado were paid depending on the objects finalized at the end of the day, for instance, finishing a total of 642 retorts would earn a glassmaker two pesos in 1778. Later, in the early nineteenth century the payment was done by the dozen (Peralta Rodríguez and Alvízar Rodríguez 2010:10-11). This kind of output seems reasonable if the production was carried out by a team of artisans as it is done in Jalisco today, where those workshops that have two active furnaces can produce between 600 and 1000 pieces per day (Castillo Cárdenas 2016:31).

Although the main glass product made at the Casa del Apartado were the retorts for gold parting, towards the end of the eighteenth century other products were added to their repertoire of glass products including alembics, funnels, mortars, pestles, and bottles of different shapes and sizes, for instance, bottles with long necks known as *limetas,* as well as *jaroperas,* which held syrups, and *daditos*, tiny bottles with a quadrangular section. Many of these items were requested by local apothecaries as well as by those in La Habana. The Casa del Apartado also sold raw materials needed for glassmaking, such as sand and *barrilla* to other glass workshops in the city (Peralta Rodríguez 2014:76-77; Peralta Rodríguez and Alvízar Rodríguez 2010:13-14).

Given the constant need for retorts for the gold parting process, royal authorities made sure that the glass furnaces at the Casa del Apartado were stocked with everything needed. However, there were several times in which there was a shortage of raw materials. When this happened, the administrators first looked for solutions that could be implemented internally, but at times, vice regal authorities intervened and emitted ordinances that would ensure that the raw materials needed were supplied.

The glass furnace at the Casa del Apartado also kept track of its expenses. The following is the transcription and translation of the Memoir no. 54 of expenses from the week of November 21[27] to 27$^{th}$, 1795:

> Materials and other expenses
> For five and a half reales [paid] to the *mozo* (young worker) that sweeps the street
> For three pesos one real of 10 *viajes* (trips) of clay and sand at 2 ½ reales
> For four reales to pay the carpenter to place four locks on the *rastras* (lattices) in one real
> For two pesos three and a half reales for 19 arrobas 13 pounds of *cortaduras* (cullet) of ordinary glass at one real the arroba
> For three and a half reales for 1 arroba 18 pounds of *cortaduras* (cullet) of fine glass at 2 reales the arroba
> For one peso three quarter reales for 3 arrobas 20 pounds of Castilian *casco* at 3 reales the arroba
> For one peso for one *velada* (vigil) in the kilns for *pasteladura* (batch of raw glass)
> For one real payed to the one who loaded the aforementioned kilns
> For three pesos four and a half reales for two dozens of *chiquiguites* (baskets) at 11 reales the dozen and half a real for the carrier
> For five pesos four reales for 7 dozens 4 large *tapas* (covers or lids) at 6 reales the dozen
> For one peso one real for 6 ordinary *piedras de cantería* (quarried stones) for *ampareadura* (protection?) of the glass furnace at 1 ½ reales each
> For six pesos one real for 7 loads of of coal at 7 reales
> For four pesos for the carpenter for a new patch on the *torno de cernir barilla* (sifting lathe)
> For four pesos for the one who takes care of the sewage
> For six pesos for the blacksmith for fixing various *fierros* (jacks)

For forty-one pesos three reales for 44 loads, 7 *manos* (bundles) of cedar wood at 7 ½ reales the load of 50 *manos*
For eighty-one pesos one and three quarter reales for 68 loads, 40 *manos* of *ocote*[207] wood at 9 ½ reales the load of 100 *manos*
For forty-three pesos one and a half real payed to the bachelor Don Francisco Guerra Manzanares for the rent of the *corralón* (corral) of the Casa del Sopilote for 4 months in a row since April 12 of the present year until 12 of the current at 130 pesos per year
Is the sum of the material and other expenses (as it seems) two hundred five pesos six and a half reales

Salaries and wages
For fourteen pesos for Don Manuel Bengoechea for 7 days at 2 pesos
For seven pesos for the substitute of Mendivil of for days at 1 peso
For seven pesos for the substitute of the doorkeeper for 7 days at 1 peso
For five pesos two reales for the *guardapito* (night guard?) for 7 nights at 6 reales
To López, for 51 *cornamusas de arca* (retorts) at 2 pesos the hundredth and 6 floor mortars at 9 reales, seven pesos six reales
To Pisa, for 322 said [retorts] and 5 mortars, twelve pesos and a half
To Macario, for 238 said [retorts] and 4 mortars, nine pesos two reales
For twelve pesos six reales for 27 *2*(jacks) at 2 reales and 12 *arcas* (two-pronged forks?) at 4 reales
For fourteen pesos given as a ration to the 6 *atizadores* and the muleteer taken from their monthly salary at 2 pesos each
For one peso *yd.* (given in the same way) to the apprentice Rebollo
For 30 days payed to the inside *peones* (workers) at 2 ½ reales, nine pesos and three reales
For 76 pesos 1 real for the *mozos* of gold-parting in this way: 6 reales for the capitan, 5 ½ for his second, 4 skilled at 5 reales, 4 not so skilled at 1 ½ reales, 10 regular at 4 reales, and 2 washers at 6 reales

Masons of the glass furnace
For 6 days to one officer at 6 reales, four pesos for reales
For 11 said [days] to other two officers at 5 reales, six pesos seven reales
For 53 said [days] to 9 *peones* at 3 reales, nineteen pesos seven reales
For 6 said [days] to one *cabrito* (youngster) at 2 ½ reales, one peso seven reales
Is the sum of the salaries and wages (as it seems) two hundred eight pesos five and a half reales
The previous of materials two hundred five pesos six and a half reales
And the total of both chapters four hundred fourteen pesos four reales
For three hundred six pesos and three quarter reales of the Memoire no. 33 of the previous week that was not charged
Minus three hundred ninety pesos three and a quarter reales in this way namely = 364 pesos 3 reales for 530 pounds of *aguafuerte* (nitric acid) sold to the Relatura de Casa de Moneda (mint) in the past month of July at 5 ½ reales the pound = 19 pesos 7 reales for 26 ½ said [nitric acid] sold to an apothecary at 6 reales = 4 pesos 3 ¼ reales for 23 ½

[207] *Ocote* is a type of pine tree that grows in Mexico.

arrobas of useless *barrilla* at 1 ½ reales the arroba = one peso for 2 arrobas of the good one [*barrilla*] at 4 reales = six reales of small *matrazes* (flasks) at 3 reales
Leaving liquid and to pay (except error) three hundred thirty pesos seven and a half reales
Which memory goes truly deduced from the respective books, papers, and documents in which, separately, the accounts and reason of everything are kept, and we swear for God our lord and the signal of the holy cross to be truthful, legal and veritable without fraud nor concealment against the Royal Hacienda.
Apartado General of the kingdom and August 25, 1795
Pasqual Ignacio Aperechea [rubric] Antonio Arenal [rubric][208]

This record illustrates the many people who worked in the glass furnace of the Casa del Apartado as well as some of the raw materials used. In this case, some of the workers as well as the materials presented were probably not exclusive of the glass furnace, but may have been involved in other activities carried out in the gold-parting institution. People like the guardians, the sweeper, or the one who took care of the sewage probably performed duties throughout the building; a*tizadores* could probably work indistinctly in the different firing facilities; and muleteers were probably providing services for the place as a whole. The people working in the glass furnace included three officers, one of whom received a higher wage, nine *peones*, and a youngster. The purchase of 27 jacks and the payment to a blacksmith for fixing the existing ones speaks about the intensity of the work of glass artisans. According to glassmakers in Puebla and Jalisco jacks need to be replaced every four years, and more often in the case of inexperienced artisans (Castillo Cárdenas 2016).

Wood was needed to fire all the furnaces, but this record specifies the preference of two particular kinds: *ocote* and cedar, while coal was also available as a third source of fuel or to use in stoves. In terms of raw materials, the ones associated with glassmaking include: sand, ordinary and fine cullet, Castilian *casco*,[209] and good and bad *barrilla*. The report also sheds light into

[208] AGN, Casa de Moneda, vol. 246, fs. 16-17.
[209] The term *casco* is used in some glass recipes to refer to and intermediate stage in glassmaking, as will be shown later. In this context it might refer to ingots made from Castilian glass cullet.

some technical aspects such as the care needed to make *pasteladura* (batch of raw glass), which meant having someone stay overnight to monitor the process. It also tells us that there was a sifting lathe for the processing of *barrilla*. To facilitate the melting of the components when making glass and avoid remains of unreacted material in the glass, all the ingredients need to be finely ground and sieved. Perhaps the sifting lathe aided in this process.

Having a reliable supply of *barrilla* was crucial for the glass workshop at the Casa del Apartado. There were certain years in which obtaining this resource was problematic. In July 22nd, 1796 for instance, the Apartador General Pasqual Ignacio de Aperechea complained that the Indians of Xaltocan, who were the sole providers of *barrilla,* had been called to work on a drainage project and for this reason they argued that they should be excused from their regular task of collecting *barrilla*. Aperechea feared that the best *barrilla* fields would flood and the harvest would be lost, as it had happened the year before. Thus, the Apartador General requested that for the time of harvest, which was about to start, the Indians of Xaltocan were excused from their duties in the drainage project.[210] The request was accepted, but this did not prevent the fields from flooding, so it became necessary to search for it in other areas. The quality of the *barrilla* varied depending on the area where it was collected, and the one they found did not contain sufficient salts, forcing the glassmakers to perform multiple trials which resulted in a lot of failure and waste until they were able to produce glass of sufficient quality. For this reason, Aperechea proposed to rent some lands where the seeds of *romerito* (another term for *barrilla*) could be planted in the area of the Hacienda de Aragón, owned by the Indians of Santiago Tlatelolco. He believed the lands would be suitable after sprinkling the lands with *tequesquite* to increase its salt content. He considered that the King could easily get the land from the Indians

[210] AGN, Casa de Moneda, vol. 46, exp. 20, fs.1-3.

without causing any grievances given that they would receive a rent. Soon, an order was emitted for the appraisal of the lands to begin the negotiations.[211] However, getting access to the lands proved to be harder than expected and Aperechea went back to the Indians of Xaltocan, who reported there was *barrilla* available but the danger of flooding remained. That summer, he reported receiving more than a thousand arrobas of *barrilla* from a different area, los Porteros del Peñol.[212]

Shortages were also experienced with other raw materials. In 1812, there was a scarcity of the flint sand used to make the glass. Although only one furnace was active, the superintendent requested permission to suspend all activities in the furnace until the sand needed was available. Permission was granted after confirming that there were 13,400 glass retorts available in storage. The stored retorts provide an example of the considerable output of the glass workshops at the Casa del Apartado. The suspension of activities at the furnace also implied that firewood would not be needed in the same quantities so notification was sent to Juan Bautista de Arroyave, who brought the wood from Chalco, that he should interrupt the supply of wood until further notice.[213] It is unknown when operations were reassumed, but production recovered. By 1829, there was so much exceeding glass at the Casa del Apartado that the accountant Manuel Diaz Moctezuma recommended that it was used to make glass vessels to sell to the general public.[214]

The issues faced by the administrators of the Casa del Apartado in terms of raw materials availability and supply illustrate the importance of this part of the glassmaking *chaîne opératoire*. Failure in the provision of one of the raw materials was enough to stop the whole

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[211] AGN, Casa de Moneda, vol. 46, exp. 20, fs. 6-9v.
[212] AGN, Casa de Moneda, vol. 46, exp. 20, fs. 22-23.
[213] AGN, Casa de Moneda, vol. 46, exp. 11, fs. 2-3.
[214] AGN, Casa de Moneda, vol. 182, exp. 8, fs. 181-183v.

operation. Apartador General Aperecha complained that the Casa del Apartado was at the mercy of the Indians of Xaltocan in terms of obtaining a regular supply of *barrilla.* As will be discussed in the following section, the reliance on indigenous people was true in more than one way.

### 6.9. Raw Material and Fuel Procurement

As we have seen, both private glass workshops and the Casa del Apartado, depended on more than the glass artisans and the rest of the workers in the furnaces. Firstly, glass workshops needed lots of glass to make the products, so having the raw materials needed to make it was essential. Secondly, glass requires extremely high temperatures not only to melt the sands, but to keep the glass molten and red hot in order to be workable. Hence, having a constant supply of fuel, which in colonial Mexico was wood, was imperative for successful production.

Although indigenous people do not figure prominently as artisans in the glass workshops and their presence as such is only evident at the end of the eighteenth century, the fact is that they played a paramount role in the establishment, adaptation, and development of the glass industry in colonial Mexico. I consider that the transfer of glass technology to the Americas would not have been possible, nor successful without the reliance on indigenous traditional ecological knowledge and labor.

It makes sense that the glassmakers arriving in New Spain tried to replicate the technology that they were familiar with in their homeland, which at the time was based on the use of halophytic plant ashes to make glass. So in order to practice their craft, they first had to find the three main components needed to make it: 1) sand as a source of silica; 2) ashes from plants similar to Spanish *barrilla* as a source of alkali; and 3) a calcium-bearing component such as lime. Depending on the type of sands used, however, it was not always necessary to add the third component. Costal sands, for instance, can contain substantial amounts of seashell fragments, providing the calcium needed to make stable glass (Henderson 2013: 329). We do not know how glass artisans went about finding these resources but given that there was no glassmaking in the Americas, they probably had to find the raw materials themselves. The earliest attempts at glassmaking must have involved a lot of trial and error experimenting with different sands and plants collected from brackish lagoons, but eventually, they figured out which resources worked.

The historical records reviewed so far provide us with important clues of the raw materials that became prevalent in colonial glassmaking: different types of sands, *barrilla* plant ashes, and *tequesquite*. The records do not provide much information regarding sand sources, Humboldt (1966 [1822]:459) mentions that the flint sand used in the Casa del Apartado was obtained in Tlalpujahua, Michoacán, and there are sources of high quality sand in Jáltipan, in the south of Veracruz (Melgarejo Vivanco 1960:237). There is one more clue on another possible source of sand in a historical document from 1557 related to a majolica potter who struggled making glaze in Mexico City until he found adequate sand in the Ventas de Perote (Gómez Pastor and Fournier 2001:36, 38, 46), in the valley of Temazcalapa, close to Jalapa, Veracruz (Gerhard 2000:387). It is possible that the sand from that source may also have been adequate for glassmaking. The expense reports of the Casa del Apartado show that trips of sand and clay were bought on a weekly basis, but sometimes they also included a couple or as many as 43 loads of *arenilla de pedernal* or flint sand,[215] which suggests that they used sands of different qualities that must have come from different sources. The possible areas where sand may have been collected identified so far in historical documents can be seen in Figure 58.

[215] AGN, Casa de Moneda, Vol. 246, fs. 52, 204.


Figure 58. Possible areas of sand collection according to historical sources.

Identifying the right plants to obtain the alkali-rich ashes for glassmaking seems to have been one of the priorities of the newly arrived glassmakers in the 1530s. By this date, several expeditions were launched to explore the continent and learn about the available resources. Given that the process to make glass was unknown to the local people, early colonial glassmakers probably had to rely on their own searches or on word of mouth. It seems that not only glass artisans, but Spaniards in general, were familiar with the plant used for glassmaking. When López de Gomara (1943 [1553]:413) narrates the expedition that Cortés made to Jalisco, Nayarit, and Baja California in the 1530s, he mentions that the Spaniards who stayed in Bahía Santa Cruz (Baja California Sur) were so weak that they could no longer fish and had to rely only on wild fruits and "the herbs used to make glass." His comment implies that he assumed that people were familiar with the "herbs" (or plants) he was referring to. Accounts like this one, confirm the importance of explorers in the identification of a variety of resources not only for colonial authorities, but also for many artisans starting up workshops in the New World. The fact that he identified a maritime plant as the plant that was used to make glass suggests he was familiar with Spanish *barilla*, which is maritime and grows in the coast (Frothingham 1963:11). The genera *Salsola*, which was the one used for glassmaking in the Iberian Peninsula, is not, however, endemic to the Americas. It was introduced into the continent by Europeans often as forage, like the case of *Salsola tragus*, but in many cases unintentionally (Espinosa-García and Villaseñor 2017:82). *Salsola kali*, which is native to Eurasia and is the most commonly mentioned as a source of alkali for glassmaking in publications, can be found today in the north of Mexico and some central states such as Zacatecas and San Luis Potosí (Calderón de Rzedowski and Rzedowski 2001:123; Rzedowski 1959:53, 55). However, its distribution, mainly in the north of Mexico, does not coincide with the areas mentioned in the historical documents regarding glassmaking: Michoacán in the early colonial period, and later in the Valley of Mexico,[216] as will be shown below. *Salsola kali* seems to have entered accidentally into the Americas in flaxseed or linen seeds brought to South Dakota in the 1870s, from where it propagated (Robbins et al. 1951:158; Rzedowski 1959:54). Considering its late introduction and northern distribution, it seems unlikely that *Salsola kali* was ever used as an alkali in colonial Mexico. In addition, there are no later documents that mention the use of plants from Baja California in relation to glassmaking so its exploitation for this purpose is improbable.

Eventually, Spanish glassmakers found suitable local plants that worked like the *barrilla* that they used in their homeland, and once they did, colonial glassmaking began to develop. Studies on the use of halophytic plants for glassmaking in the Middle East, Egypt, Europe, and the Levant (e.g., Barkoudah and Henderson 2006; Brill 1970; Henderson 2013:23) have shown that a wide variety of halophytic or salt-tolerant plants of the Chenopodiaceae family can be used in glassmaking; these include the genera *Salsola, Suaeda, Salicornia, Artiplex, Halocnemum,*

[216] Calderón de Rzedowski and Rzedowski (2001: 123) affirm that this species is scarce in the Valley of Mexico.

*Anabasis, Arthrocnemum, Halopeplis,* and *Hammada* to mention a few (Henderson 2013:23). In Spain, the most commonly used plant, popularly known as *barrilla*, seems to have been costal saltworts of the genera *Salsola* (Fernández Pérez 1998) collected in Alicante, Valencia, and Murcia. This resource was considered to be of such high quality that it was exported throughout Europe (Frothingham 1963:II).

Given that the plant used in New Spain was referred to also as *barrilla*, there are two possibilities: 1) the plant was brought to the Americas and cultivated for this purpose, or 2) a similar endemic plant was used. In colonial Mexico, however, the halophytic plants used for glassmaking did not came from the coast. Historical documents indicate that this resource was collected in Michoacán and later in the Valley of Mexico, both of which are located inland. Curiously, the only three ordinances related to glassmaking in New Spain were all about the collection of this resource. The first one, dated to October 10th, 1596, stated that given the need for glass tableware in New Spain, glass artisans should be helped and favored so that they would continue practicing their craft, and because they needed *barrilla* to make glass, any person who collected this resource had to declare it to the authorities, otherwise they would have to pay a hefty fine and the *barilla* would be distributed to glassmakers (Fernández 1990:60, 62).[217] It seems that the proclamation of this ordinance did not worked as expected because shortly after, on December 3rd of the same year a second one was issued. In this one it was again demanded that any person who collected or bought *barrilla,* particularly from Guayangareo (today Morelia) and Cuitzeo in the province of Michoacán, should declare it to the authorities, informing them of the quantity and the place where it had been collected to avoid its accumulation and the increase on its cost, and so that it could be distributed to the artisans who used it (Fernández 1990:58-

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217 AGN, Reales Cédulas Duplicadas, Vol. 3, Exp. 161, fs. 120v-122.

59).[218] Pedro Gutiérrez de Cuevas described Lake Cuitzeo in 1579 as part of a provincial report included in the *Relaciones Geográficas*, a series of documents with descriptions of the Spanish American territories sent to the King of Spain. In his description he said:

> "This lagoon, one and a half *vara* deep, faces the winds from north and south, when it ebbs the soil is curdled with *tequesquite* that is used to make soap. Between this *tequesquite* grows a plant from which glass is made that the native call *curiraxaqua*. Here come the glassmakers from Mexico City to collect it and take it back in cakes of a peso in price" (Acuña 1982:86).

From this description we know that glassmakers in the late sixteenth century considered it was worth to make a trip to those faraway lands to get this resource, which apparently was also processed there into cakes. *Barrilla* and its processing in Alicante, Spain was described in 1621 by James Howell as follows:

> "I am to send hence a commodity call'd barillia to Sir Robert Mansel for making crystal glass… This barillia is a strange kind of vegetable, and it grows nowhere upon the surface of the earth in that perfection, as here… it is an ingredient that goes into the making of the best Castile soap. It grows thus, 'tis a round thick earthy shrub that bears berries like barberries, betwixt blue and green, it lies close to the ground, and when it is ripe they dig it up by the roots, and put it together in cocks, where they leave it to dry many days like hay, then they make a pit of a fathom deep in the earth, and with an instrument like one of our prongs, they take the tuffs and put fire to them, and when the flame comes to the berries, they melt and dissolve into an azure liquor, and fall down into the pit till it be full; then they dam it up and some days after they open it and find this barillia juice turn'd to a blue stone, so hard, that it is scarce malleable; it is sold at one hundred crowns a tun, but I had it for less" (Howell and Jacobs 1890 [1621]:60)

Considering that the glassmakers took the *barrilla* back to Mexico City in the form of cakes, it is possible that a similar process to the one described above was followed. The glassmakers probably learned the process back in their homeland and eventually must have taught it to the people who collected it.

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[218] AGN, Reales Cédulas Duplicadas, vol. 3, exp. 161, fs. 120v-122.

It seems like glassmakers continued to struggle procuring enough *barrilla* because a third ordinance was emitted on January 30, 1617, but this time it was a lot more restrictive, stating that the collection of *barrilla* should be collected only by Indians or people that the glassmakers or *apartadores* designated to procure it for them. One of the reasons given when the petition was made was that it was needed to make glass retorts for gold parting, which as previously mentioned, was of great interest to the Crown. The ordinance also restricted the collection of *barrilla* before it fully matured because otherwise it would not absorb enough salt from the soil resulting in bad quality glass, the breakage of the retorts under the heat during the gold parting process, and the spillage of the metals in the furnace, which could not be fully recovered (Fernández 1990:63-64).[219]

The *barrilla* from Michoacán continued being highly valued and use throughout the seventeenth and eighteenth centuries. When describing the province of San Nicolás de Tolentino de Michoacán in 1673, Diego Basalenque (1886 [1673]:292) mentions that in the dry season, it was possible to collect *barrilla* in Lake Cuitzeo, and that although this resource could be found in other parts, the one from Cuitzeo had no equal regarding its good quality. Later, the Augustinian friar Mathías de Escobar (2008:92-93), who wrote about the province of Michoacán between 1729 and 1743, mentioned that the plant used for glassmaking grew at the edge of Lake Cuitzeo, and that it was the best and finest to make clear, transparent glass.

Another area where *barrilla* was collected was the north of the valley of Mexico. From the documents of the Casa del Apartado we know that the plant was collected by the Indians of Xaltocan, whose town was located close to brackish Lake Xaltocan. The Casa del Apartado heavily relied on them to procure this resource and this is evident in the regular purchase of up to

[219] AGN, Ordenanzas, Vol. III, fs. 38-39v.

139 arrobas of *barrilla* from the Indians of Xaltocan manifest on the reports of weekly expenses,[220] as well as on the petitions made to excuse them from working on the drainage project so that they could perform their usual task of collecting *barrilla*.[221] From one of the expense reports of the Casa del Apartado made in July 1796 we know that it provided the Indians of Xaltocan with tools because they purchased "…23 iron *coas*[222] that weighted 63 ½ pounds, at 3 reales the pound, that were bought to enable the Indians of Xaltocan to cut the plant to make *barilla.*"[223] This indigenous community not only provided harvested *barrilla*, but also *romerito* seeds to grow it,[224] which the Casa del Apartado bought from them shortly after Aperechea had proposed to rent extra land for this purpose.

Neither Lake Cuitzeo, nor Xaltocan are close to the coast. Regardless, the plant collected in both areas came to be known as *barrilla,* the same name used in Spain to refer to the plants used for glassmaking. The fact that those were costal, and the ones in New Spain came from inland saline lakes was not consider significant enough to call the American plants a different name.

The identification of *barrilla* plant is complicated because the name *barilla* is no longer in use and raw glass is now made using pure chemicals. Several different plant species have been proposed by different authors as candidates for *barilla*. Starting with Humboldt (1966 [1822]:459) in the nineteenth century, who believed this resource could come from *Sesuvium portulacastrum*, *Salsola soda* and several species of *chenopodium*, *artiplex*, and *gratiola*. In particular, he identified the barilla collected in the valley of Mexico as *Salsola Soda*. Fernández

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[220] AGN, Casa de Moneda, vol. 246, f. 204.
[221] AGN, Casa de Moneda, vol. 46, Exp. 20, fs.1-3; AGN, Casa de Moneda, vol., 760, Exp. 115.
[222] The *coa* is an agricultural instrument of prehispanic origin similar to a hoe that was used in Mesoamerica and it is still used by farmers in Mexico today. Although they were traditionally made of wood, the ones provided by the Casa del Apartado to the Indians of Xaltocan were made of iron which probably helped them last longer.
[223] AGN, Casa de Moneda, vol. 246, f. 248.
[224] AGN, Casa de Moneda, vol. 242, f. 2, 5, 77; AGN, Casa de Moneda, vol. 246, f. 158, 383, 399.

(1990:64-65) believe that barilla was *Salsola kali* based on one example from San Luis Potosí that he saw in the Herbarium of UNAM, and he also said that today the plant is known as *maromero*. Peralta Rodríguez (2018:9) proposes three options but only identifies them by their colloquial name: *maromera*, *saladilla*, and *romerito*. Martins Torres (2019a:582) presents five candidates after considering a variety of historical botanical treaties: *Salsola soda*, *Sesuvium portulacastrum, Chenopodium maritimum, Chenopodium ambrosoide,* and *Heliotropium curassabicum.*

As mentioned above a variety of halophyte plants can be used for glassmaking, so it is possible that various species were used simultaneously, particularly during the Early Colonial period when glass artisans were experimenting with different resources. However, there are several aspects that need to be considered. Halophyte plants are able to tolerate high levels of alkali from the soil by accumulating sufficient salts in the leaves for osmotic adjustment[225] while at the same time preventing the accumulation of toxic levels of salt within; when excess happens, the leaves turn black and fall off. But there are significant differences between species in the internal accumulation of salts at which toxic effects of salts become evident (Gorham 1996:35-36), which means that not all halophyte plants are good sources of alkali for glassmaking. To be suitable for glassmaking, the alkalis in the halophyte plants must be in the form of carbonates, bicarbonates, sulphites, sulphides, and hydroxides, rather than chlorides of sulfates (Tite et al. 2006:1285). Most importantly, they must contain sufficient quantities of sodium carbonate ($Na_2CO_3$) when ashed, because this is the compound that interacts with the silica (Henderson 2013:23). Secondly, historical sources provide us with clues of the places of recollection, namely Lake Cuitzeo, Guayangareo, and Lake Xaltocan, which should also be taken into account when

[225] The high osmotic pressure (low water potential) of the soil tends to withdraw water from the plant, so the plant must be able to adjust its internal osmotic potential to delay wilting (Gorham 1996: 34).

considering possible candidates for *barrilla*. Unfortunately, no information on the places of collection in Puebla has yet been found, but there is a brackish lagoon where *tequesquite* is collected today that represents a good candidate, the lagoon of Totolcingo. Botanist María Hilda Flores Olvera (personal communication, January 2018), suggests two endemic halophyte plants that represent potential candidates for *barrilla*: *Suaeda edulis* (Figure 59a) and *Suaeda pulvinata* (Figure 59b). Both of these species have the characteristics necessary to provide the alkali for glassmaking, specifically succulent leaves that present large vacuoles in enlarged cells where the salts accumulate, among other salt-tolerance mechanisms (Gorham 1996:45); their distribution coincides with the areas mentioned in the historical documents (Figure 60) (Fernández 1990:58; Peralta Rodríguez 2018:10); and according to Flores Olvera (personal communication, January 2018), they would have been abundant in the sixteenth century. *Suaeda edulis* can be found in the saline lakes of Guanajuato, Jalisco, Michoacán, the valley of Mexico, Tlaxcala, and Puebla (Noguez-Hernández et al. 2014:20). *Suaeda pulvinata* inhabits Lake Texcoco, in the valley of Mexico, and Lake Totolcingo, in Puebla/Tlaxcala, as well as the Chihuahua desert (Alvarado Reyes and Flores-Olvera 2013:311).

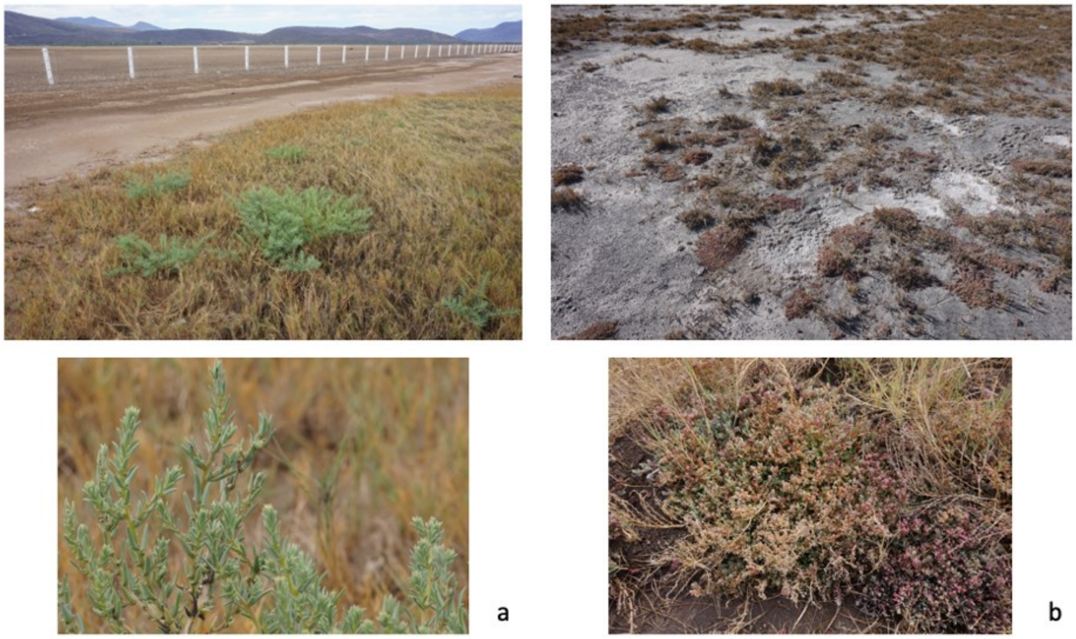


Figure 59. Mexican halophyte plants, potential candidates for barrilla: a) *Suaeda edulis*, Lagoon of Sayula, Jalisco; b) *Suaeda pulvinata*, Lagoon of Totolcingo, Puebla/Tlaxcala (photos: Karime Castillo).

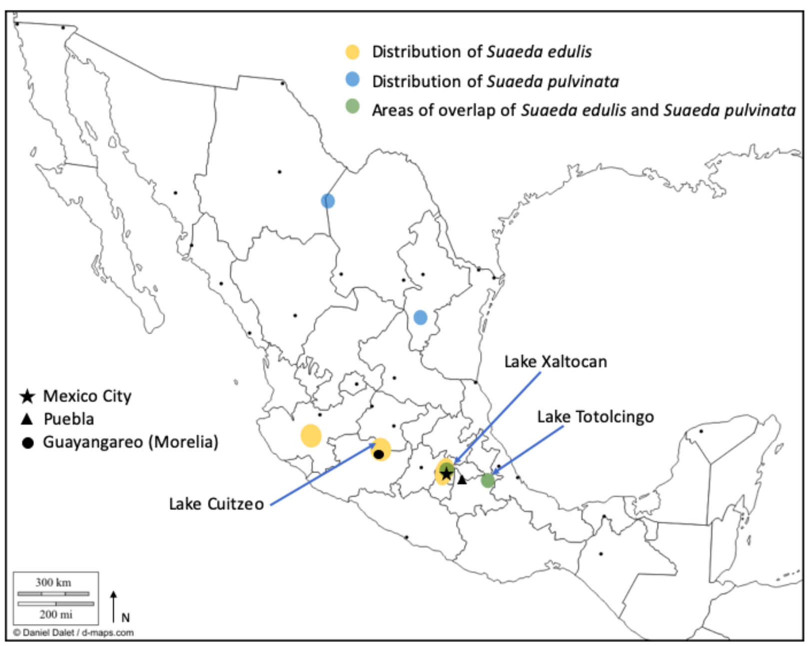


Figure 60. Distribution of *Suaeda edulis* and *Suaeda pulvinata* in Mexico.

Lastly, the ordinances provide an important clue regarding the possible species when it was necessary to emit a restriction to collect the plant before it matured. Such a restriction would have been unnecessary if it was used only to obtain soda because fully mature *barrilla* would have sold better and resulted in more profit. But the fact that a restriction was put in place means that the immature plant must have been collected in significant quantities and used for other purposes. The records from the Casa del Apartado provide a clue in the name of the seeds bought from the Indians of Xaltocan: *romerito*. As mentioned above, *Suaeda edulis* is the wild version of the *romerito* cultivated today in Mexico for the food market (Noguez-Hernández et al. 2014:20). This plant has been part of the culinary tradition of central Mexico for centuries, probably dating back to prehispanic times (McClung de Tapia et al. 2014:114; Urbina 1904:559), and may have been known as *iztaquilitl*, which Sahagún (1577:XI,136) described as a low plant of salty flavor that was eaten cooked and uncooked. Even today, it represents the main ingredient of some traditional dishes that are consumed in Christmas and Easter. For cooking purposes, *romeritos* are collected when the plants are young, so that they are tender and not too salty. The use of this resource by indigenous communities as part of traditional foodways in the Colonial period might explain its collection before the plant was fully grown and the need to restrict this practice. The fact that the ordinances allow indigenous people to collect it may have been linked to their role as providers of this resource for glassmaking, as shown in the records of Casa del Apartado. While those records date to the eighteenth century, it is possible that the dependency on indigenous labor and traditional ecological knowledge went back to the early seventeenth century considering that the Indians of Xaltocan had been exploiting the resources of the area for centuries.

Another resource used in colonial glassmaking was *tequesquite*. In the expense reports of Doña Micaela's workshop *tequesquite* appears frequently. Those from the Casa del Apartado sometimes mention the purchase of up to twelve loads of *tequesquite*,[226] but this material was not bought as frequently as sand or *barrilla*, both of which appear regularly on these reports. This was probably because the preferred alkali was *barrilla*, following the peninsular glassmaking tradition. Frequently purchased or not, *tequesquite* was an important material for glassmaking in colonial Mexico, as will be explained in the next section. For centuries, and perhaps for millennia, *tequesquite* was obtained along the margins of brackish lakes in central Mexico during the dry season, when substantial salt crusts form naturally. These crusts would then be dried, pulverized and cleaned for use (Parsons 1996:447; Williams 2016:52). The process can be intensified by preparing artificial beds separated by water canals (Figure 61, left), with water evaporation stimulating the efflorescence of the soluble salts form the soil. This process is still carried out today at Lake Totolcingo in Puebla/Tlaxcala by community members of Santa María Tequexquitla, Tlaxcala (Figure 61, right).

Figure 61. Artificial solar-evaporating bed for the collection of *tequesquite* (left) and collection of *tequesquite* in the Lagoon of Totolcingo, Puebla/Tlaxcala (right) (photos: Karime Castillo).

[226] AGN, Casa de Moneda, Vol. 246, f. 249.

Given the long-established tradition of *tequesquite* collection and use by indigenous communities as a condiment for food (Williams 2016:139), it was probably them who supplied this material to glassmakers and other industries.

*Tequesquite* was used not only in glassmaking, but was a vital ingredient in the making of soap, which was one of the main products made in colonial Puebla until the nineteenth century. It was collected from the *salitreros* of Vicencio and Ojo de Agua, located between San Marcos and Oriental, where is still collected today, and sometimes it was brought from Texcoco in the basin of Mexico (Cordero y Torres 1965a:219). *Tequesquite* was also used for cooking, particularly to soften and season meats and vegetables such as corn, and as an ingredient in some medicines (Barros and Buenrostro 2007:147; Fernandez de Echeverria y Veitia 1962 [1780]:303). By the beginning of the nineteenth century, it was purified and used for dissolving the muriates and sulphurets of silver (Humboldt 1966 [1822]:170, 454).

Humboldt (1966 [1822]:453) mentions that *tequesquite* – which he described as clayey soil impregnated with soda carbonate and salts – could be found in most of central Mexico. In the month of October, in the Valley of Mexico, the surface of the land around Lake Texcoco, Lake Zumpango and Lake San Cristobal is covered by this salt efflorescence; it was also found in the vicinity of Puebla, in the area between Celaya and Guadalajara, in the valley of San Francisco in San Luis Potosí, and around the lakes in Zacatecas.

Indigenous people were also vital in the collection and transport of another crucial material for glassmaking: wood, the primary fuel for the furnaces (Lira 1990:118). From the beginning of the industry in New Spain, fuel procurement was a challenge. In 1550, viceroy Antonio de Mendoza was already showing concern regarding deforestation and issued ordinances to regulate the wood and coal that indigenous people were in charge of transporting

(Lira 1990:118). Indigenous communities had heavily exploited the forests in prehispanic Mesoamerica for the production of lime for the plastering of architectural structures, as has been investigated by Barba and Córdova Frunz (1999), and their labor may have also been required by Spaniards to obtain this resource.

While silver processing was the industry that consumed the largest amount of wood for fuel (Lira 1990:118-119), we should remember that glassmaker Rodrigo de Espinosa consumed enough in 1543 for the Cabildo or city council of Puebla to restrict him from cutting it within two *leguas*[227] of the city or acquiring it from someone else (Fernández 1990:46, 227). It appears that obtaining the ideal wood for the glass furnaces in Puebla became even more difficult in the eighteenth century because Fernández de Echeverría y Veitia (1962 [1780]:305) mentions that high-temperature burning woods could only be found eight to ten *leguas* away from Puebla, and bringing them to the city was overly expensive.

We know that firewood for the Casa del Apartado was brought from Chalco and that two types were preferred, *ocote* and cedar. Considering the high temperatures needed for glassmaking, a preference for resinous woods such as cedar and pine, which would burn well and produce a lasting fire, is expected.

One last clarification needs to be made regarding wood use in glassmaking. It has been suggested that in the Early Colonial period wood ash may have been used as a source of alkali, which would be linked to the deforestation that lead to the restriction in Puebla on the area where glassmakers could obtain wood (Cordero y Torres 1965a:220; Leicht 1934:188). The tradition of using forest plants such as mature trees and ferns to produce potash rich ash was prevalent in Northern Europe, whereas southern European glassmakers form Spain and Italy obtained their

[227] Measuring unit equivalent to 5,572 meters.

alkali from marine or desert plants (Jackson and Smedley 2004). Considering that glassmaking tradition that made its way to the Americas was the Spanish one, which relied on halophyte plant ashes, and the fact that *barrilla* is recurrently mentioned in colonial inventories and furnace records, it is unlikely that wood was used as a raw material for glassmaking in New Spain. Wood was, instead, the main source of fuel, which explains its abundant exploitation.

It is evident that glassmakers relied heavily in indigenous communities for the procurement of crucial raw materials for glassmaking, some of which, like *barilla/romerito* and *tequesquite* had been part of their foodways since prehispanic times. Glassmakers relied on indigenous labor and traditional ecological knowledge to procure the resources needed for their craft. The development of glass technology in colonial Mexico would not have been possible without them.

6.10. Technical Reports and Glass Recipes

An additional source to understand glass technology in colonial Mexico and its later development can be found in technical reports and glass recipes. These kind of documents have been extremely useful for the study of glass technology in the Roman Empire (Degryse and Schneider 2008; Freestone 2008; Jackson et al. 2018) and Medieval Europe (Freestone 1992; Caroline M. Jackson and James W. Smedley 2008; Smedley et al. 1998). While so far no glass recipes have been found related to colonial glassmaking in Mexico, there are some reports from the glass workshop in the Casa del Apartado, that discuss technical aspects of glassmaking, particularly regarding the difficulties that glass artisans sometimes experienced when preparing a glass batch. One example is a *razón* or report made on August 25 of 1796 in which the glassmaker commented that after preparing the *pasteladura* in the old furnace using seven *barrilla* cakes the batch came out wrong due to a deficiency in salts, so they removed half of it, forming two batches, and added *tequesquite*, which improved the glass. Both batches were kept in the furnace for seven days, but after that time neither was clean, so they mixed them back together and tried making retorts, which came out whitish and *vejigosas* (blistered). In order to achieve glass of ordinary standards they tried mixing three *barrilla* cakes from the previous year and three of that year but the resulting batch was also bad. To fix it, they added *tequesquite* and finally obtained good, clean glass. The glassmaker then added that this was done to a batch that contained 70 of *arenilla* (sand) and 100 of *barilla* but does not specify the units.[228]

This report explains why two different types of alkali were present in the inventories and reports of both the Casa del Apartado and the glass furnace of Doña Micaela Gerónima Becerra. Given that the quality of *barrilla*, the preferred alkali, varied from year to year, glassmakers sometimes struggled obtaining glass of sufficient quality. When this happened, it was sometimes possible to save the glass batch by adding *tequesquite*, so it was important to have it available in the workshops. Glassmakers probably had recipes and formulas for glassmaking but in practical terms, they constantly needed to adapt to the quality of the *barrilla* available for a given year. It is also important to consider that in both the valley of Mexico and Puebla it can rain in copious quantities during the rainy season. As related by Apartador General Aperechea, when *barrilla* fields flooded they lost the salts and went to waste.[229] *Barrilla* cakes were also prone to spoiling if they got wet, so having a second source of alkali could mean the difference between completing an order or not.

In the case of Puebla, Fernández de Echevería y Veitia (1962 [1780]:304) mentions that at the end of the eighteenth century Pueblan glass was made using mostly *pedernal* (silex) mixed

[228] AGN, Indiferente Virreinal, caja 5231, exp. 32, fs. 6-7.
[229] AGN, Casa de Moneda, vol. 46, exp. 20, fs.1-3.

with *tequesquite*, and that the resulting glass objects were not long-lasting, referring not only to their breakage through regular use, but indicating that sometimes they would "open" on their own. He attributed this failure to the faulty proportions in the raw materials employed, explaining that when not enough *tequesquite* was added to aid in the melting of the *pedernal,* the glass melt retained multiple saline particles that would dilute when exposed to liquids or humidity and "open" the glass. Fernández de Echevería y Veitia (1962 [1780]:305) also mentions that glassmakers, knowing this phenomenon, were well aware of the importance in using the correct proportions of raw materials; when not enough t*equesquite* was added, the *pedernal* would not melt and could not be worked. He seems to believe that the glass would be more durable if only the glassblowers had access to the right wood, which would allow to melt the *pedernal* without the need to add so much *tequesquite*.

The description by Fernández de Echeverría y Veytia suggests that glassmakers in Puebla relied mostly on *tequesquite* as the flux and that glassmakers preferred a more pure source of silica given their preference for *pedernal* or silex. However, his observations also indicate that even after more than a century of glassmaking in this city, and the praises that Pueblan glass got by different chroniclers in the colonial period, glassmakers sometimes struggled making glass of good quality.

As mentioned above, no colonial glass recipes have been found so far, but we can learn about the later development of the technology in a set of documents from a glass workshop in Guadalajara dating to the nineteenth century (Flores Barba 2007) which offer important insights into the process followed to make glass *ab initio* at the end of the colonial period. They include detailed recipes to make colorless glass, listing the ingredients needed, and describing the procedure to be followed and expected final products.[230] A full transcription of the recipes can be seen in Appendix 6.

The recipes show that in 1820, at the end of the colonial regime, glass technology had already changed by incorporating new materials such as manganese, potash, borax, and minium or red litharge. The two recipes were designed to produce colorless glass. For this reason they required *arena de pedernal* or flint sand, which would have been purer than regular sand, as well as manganese, to neutralize any impurities in the flint sand. One of the recipes incorporates borax and minium, while the other used potassium nitrate, and potash. The glassmaking process for both recipes involved three stages. First, a frit was prepared mixing the sieved ingredients in specific quantities, extending them in the floor of the furnace, and gradually increasing the heat. Since there was no way to measure the firing temperature, the indications were to prime the fire with one or two logs, and once these stopped producing a lot of smoke, more logs should be added, proceeding in this way until the furnace was red hot or glowing. The glassmaker specifies that the right temperature would be achieved when the flame protruded slightly from the mouth of the furnace. It was necessary to periodically move the mixture so that the top layer would be moved below and what was underneath would go to the top. This would allow to eliminate moisture as well as achieving the uniform sintering of the materials into a frit, which would be ready when all the mixture had become opaque white and fluffed. At this point the flint sand would not have yet melted, but the grains would have become rounded. A frit that was well made could be then stored into boxes for future use.

The second stage was the making of the *casco* or raw glass, which was mostly composed of frit and smaller quantities of other raw materials. Everything needed to be ground and well-

[230] AHAG, Sección Gobierno, Serie Secretaría Genera, Varios Temas, Años 1791-1823, Exp. 26, Caja 2, 1820, Fábrica de Vidrio.

mixed before placing it into the crucibles to prepare the melt. This explains why glass furnaces usually had a mill among their facilities. The crucibles would be loaded in stages, adding a portion of mixture and melting it completely before another portion of the mixture was incorporated. One of the recipes required that once everything was melted, the batch was quenched by pouring it into a water basin. The glass artisan also recommended placing the iron tools in a basin with water to cool them down every time they were taken out of the furnace, so that the glass would not stick to them and also to prevent them from rusting, which would then soil the glass.

The third and final stage would result in glass that could be worked into objects. It required the *casco* from the previous step, and additional raw materials in small quantities, which in one of the recipes included adding extra frit. In all three stages a little bit of manganese would be added. The batch was once more prepared by melting part of the mixture before adding more. It was indicated that the glassmaker would know that the glass was ready when the bubbles or "eyes" were of small size. At this point the fire was lowered slightly and the melt would be left to rest for eight to ten hours until it had been refined. At that point, any floating salts would be removed and the glass was ready to be worked.

While the mechanics of the process of glassmaking had probably not changed much from the previous century, the ingredients had. These recipes indicate that lead began to be used in Mexican glass in the first quarter of the nineteenth century. The recipes also refer to the ingredients using formal scientific nomenclature such as "potassium nitrate" and "borate soda." Much of the process was based on empirical observation. Having no means to accurately measure heat, glassmakers carefully observed the length of the flames to estimate the right temperature. They also payed attention to the color and texture of the frit, as well as the appearance of the grains of flint sand to determine when it was ready. In addition, the size of the bubbles in the glass from the last stage would tell then when it was ready to be worked.

I have so far presented the information we can obtain from historical documents, but what does the archaeological material tell us? Does archaeological glass from Mexico and Puebla reflect the use of the raw materials mentioned in the documents? How does it compare to the glass from Spain? In the following chapters I evaluate these questions by looking at the chemical composition of archaeological glass collections from Mexico and Spain, and analyzing the two types of alkali mentioned in the sources, *tequesquite* and plant ashes to interpret the results.

# 7. TYPOLOGIES OF ARCHAEOLOGICAL GLASS FROM MEXICO AND SPAIN

The archaeological glass collections used in this research include materials recovered from the two main glass production centers in New Spain: Mexico City and Puebla. Glass from two Spanish localities Barcelona and Vic, in Catalonia, were also included for comparanda. Two typologies are proposed, one for the glass found in Mexico and a second one for the Catalan glass. An introduction to the archaeological context and its particular challenges is presented for each region, followed by information on the recovery of the archaeological material for each site. This information includes location occupational history, and contextual information obtained during the excavations, which forms a significant body of knowledge for the interpretation of the glass collections. The typology of the archaeological glass of the region follows the site descriptions.

## 7.1. Archaeological Glass from Mexico

The selection of the material was mostly based on what was available in the INAH repositories at both Mexico City and Puebla. For many years, glass was considered too modern of a material to be considered of archaeological interest, and until recently, it was usually reburied without being studied. For this reason, the collections of archaeological glass available are limited. The archaeological material from both Mexico City and Puebla dates mostly to the eighteenth and nineteenth centuries. Ideally, this research would have been conducted on material excavated from glass workshops found *in situ,* following practices effective in many parts of Europe (e.g., Capellà Galmés and Albero Santacreu 2015; Gregory et al. 2018; Jackson et al. 2005; Karklins et al. 2002; Tyler and Willmott 2005) because these provide the best evidence for both local production and dating. Unfortunately, no glass furnaces have been found *in situ* in Mexico City nor Puebla to this date. The collections analyzed include, however, material form a site where pieces of a glass furnace, glass production waste, glass rods, and small ceramic crucibles with glassy residue were found. This site was located in the Calle de las Moras, which today corresponds to the street República de Bolivia, no.16 (Cedillo and Gudiño 1993:3, 25). The archaeologists did not report finding evidence of a furnace *in situ*[231] or areas showing signs of the intense heat that would have been produced by such a structure, meaning that the excavation might not have covered the area where a furnace may once have stood or that this evidence was destroyed when the later structures were built. It should be noted that in that area, close to the Pulquería Celaya, is only a block away from the Casa del Apartado and that there were other workshops and glassmakers in the vicinity (Martins Torres 2019a:610-614). The presence of a significant amount of rods and small crucibles was interpreted by the archaeologists as a place where stained glass windows were made (Cedillo and Gudiño 1993:25), but making window glass would have required a furnace. Instead, the rods and crucibles suggest that lampworking, which does not require a furnace and relies on glass rods of different colors as the main raw material, may have taken place at the site. Amongst the objects frequently made by lampworkers are glass beads. A detailed study of the beads collection, which were not included in the selection of artifacts analyzed for this work,[232] can be found in the work by Martins Torres (2019a:617-623; 2019b: 145-147).[233]

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[231] For examples of archaeological remains of glass furnaces see: Capellà Galmés and Albero Santacreu 2015; Gregory et al. 2018; Jackson et al. 2005; Karklins et al. 2002; Tyler and Willmott 2005.
[232] Sampling for this study was limited to broken objects. Small objects like beads were not included to avoid damaging them.
[233] While the typological identification of the beads is excellently made, the author identifies the material as sodic-calcic glass using the problematic parameters proposed by Salas and López (2011). As mentioned in chapter 2, it is impossible to determine the composition of the glass without performing the appropriate chemical analyses.

The other type of evidence that would have been ideal for this research would have been material dating to the sixteenth and early seventeenth centuries and recovered from firmly dated contexts. Unfortunately, such material was not available in the repositories of the Salvamento Arqueológico INAH in Mexico City, or the Centro Regional INAH Puebla. As will be explained below, the archaeological contexts in Mexico City tend to be problematic, and surprisingly, glass does not appear in abundance in archaeological excavations in Puebla (Reynoso personal communication, August 2015). Despite these major limitations, this study builds on the typological work on archaeological glass from Mexico that has been developed by other scholars (Alvízar Rodríguez 2007; Hernández Arana 1980; López Ignacio 2000; Nieto Estrada 1996).

### 7.1.1. The Archaeological Sites

The collection of archaeological glass presented here came from five sites located in the historical downtown of Mexico City: Templo Mayor, Juárez 70, Bolivia 16, Libertad 35, and Apartado 14,16,19/Nigaragua 55,59,61. Except for Templo Mayor, which refers to the famous archaeological site, all the sites are named according to the modern street and lot number where the excavation took place.

All of these sites were excavated as part of salvage archaeology projects conducted by Salvamento Arqueológico-INAH. None of these collections represents the totality of the glass recovered in the archaeological interventions; rather, they represent a selection or *muestrario*[234] that exemplifies the different glass artifacts found by the archaeologists who excavated each site.

[234] Due to limitations in storage space, most of the material recovered from salvage archaeology projects is reburied at the end of the study. However, a selection that represents all the artifacts found as well as complete objects, are kept for reference in the INAH repositories.

The archaeological context in the historical downtown of Mexico City is particularly challenging due to the environmental characteristics that conditioned its formation (Fournier García 1990:21). Mexico City is located in the lowest part of the basin of Mexico, which has no natural openings for water to drain through. For this reason, heavy rains resulted in an elevation of the water level of the lagoons in the basin, causing the colonial city to flood (Carrillo Azpéitia 1992:119; Maza 1968:28). The intense exploitation of the surrounding forests to obtain construction material and fuel, together with deforestation caused by the conversion of forest areas into cultivation land exacerbated the problem by increasing land erosion and the silting of the lagoons (Espinosa López 1991:27; Fournier García 1990:21). Further, the unstable nature of lake sediments prompted architectural structures in the city to sink (Arai 1952:5; Fournier García 1990:22; Marsal 1992:52). Since the lagoons could not be dredged and it was impossible to drain the water after an important flood, it was necessary to raise the ground level with fills of dirt from the vicinity. This solution was also applied to the problem of sinking buildings (Fournier García 1990:22). Furthermore, Mexico City has been occupied uninterruptedly since prehispanic times and has undergone innumerable transformations throughout the centuries, making it necessary to consider urbanization and city growth and how these processes have influenced the formation of the archaeological record. Amongst the most disruptive operations affecting the subsoil, and thus the archaeological record, we can mention the construction of drains, the insertion of pipelines, the leveling of the ground, the erection of architectural structures, and the demolishing of buildings, all of which are common in urban settings (Fournier García 1990:22; Schiffer 1976:29).

Because of all of the issues mentioned above, the stratigraphy of Mexico City is problematic. Relative dating of stratigraphic layers is extremely difficult. On one hand, the stratigraphic position of architectural structures is not always a reliable indicator of its temporality (Fournier García 1990); on the other hand, all of these issues have resulted in a stratigraphy of fills that contain archaeological material of different chronologies which are often mixed, leaving the archaeologist with an assortment of secondary contexts to work with (Gómez Goyzueta 2007:125; Schiffer 1976). Another thing that needs to be taken into consideration is that urban archaeology usually occurs as part of salvage and rescue archaeology projects contingent to urban planning or architectural projects. This brings particular challenges for archaeologists, including conducting excavations in areas where the subsoil has already been affected by construction companies with the consequent loss of contextual information. Tight timelines imposed by construction companies or government agencies, further forces archaeologists to work at a fast pace and limit the opportunities for further investigation of a particular context (López Wario 2016:104-105). Nevertheless, the secondary deposits of Mexico City can still offer abundant information about the people that have inhabited this land and their social activities even if they cannot be linked to a specific sector of the city (Fournier García 1990:23).

All the material from Mexico City comes from excavations carried out in the historical downtown of the city, an area that has had continuous occupation since prehispanic times. The location of the sites can be seen in Figure 62. A brief description of the sites, their stratigraphy, and overview of the material in each one is provided in Table 3. Except for Templo Mayor, which was excavated by the former Departamento de Monumentos Prehispánicos (Matos Moctezuma 1990:26), all the sites were excavated by Dirección de Salvamento Arqueológico INAH (DSA-INAH).


Figure 62. Location of the archaeological sites in Mexico City.

Table 3. Descriptions of the sites in Mexico City.

| MEXICO CITY | | | | | |
|---|---|---|---|---|---|
| **Site** | **Location** | **Excavation** | **Archaeological Context** | **Glass Artifacts** | **Notes** |
| Templo Mayor | Historical downtown between the streets Justo Sierra (N), Lic. Verdad (E), Plaza Manuel Gamio (S), and República de Argentina (W). | Excavated as part of the Proyecto Templo Mayor (Matos Moctezuma 1982a, 1990; 1978a; 1978b)<br><br>Excavation Units: mostly trenches, subdivided into squares excavated in arbitrary levels. Most units were extended in subsequent seasons.<br><br>The material is part of the teaching collection of ENAH. | Stratigraphy: construction fills made up of rubble and loose dirt with mixed material.<br><br>Features:<br>• At the time of the excavation: parking lots with asphalt and cement ground.<br>• Independent period: water pipelines, telephone lines, a large water collector, remains of houses, several walls and floors, and foundations of a building demolished in 1933 (Cuevas 1990:359).<br>• Colonial period: glazed ceramic pipes, remains of floors and walls, a water well, and a midden.<br>• Prehispanic period: part of construction stages IV and V of Templo Mayor, a brazier, a Tlaloc and a serpent sculpture, and several offerings (Matos Moctezuma 1982b; 1978a; 1978b). | Total artifacts: 786<br>64% is twentieth-century glass and was not included in this study.[235]<br><br>Material analyzed:<br>· Bottles<br>· Phials<br>· Tableware (jars, wineglasses, dishes, bowls, cups)<br>· Glass production waste (glass chunks, droplets, trails, slag) | Not all the fragments are marked. Those that are marked are from excavation units opened during the seasons of March-May 1978 and October 1978.<br><br>The collection represents a mix of material collected from several excavation units.[236] |
| Juárez 70 | Lot 70 on Avenida Juárez between streets Revillagigedo (E), José Azueta (W), and the old fire inspection building (S). | Excavated as part of an archaeological rescue project (Corona Paredes et al. 2000).<br><br>Excavation Units: test pits and trenches, some of which were extended, and one extensive unit. The excavation was done by layers and arbitrary | Stratigraphy: seven fill layers with mixed material.<br><br>The lot has extensive subsoil disturbances due to the foundations of two large buildings: a colonial hospice for the poor (Blum 2001:31) and the Hotel del Prado, an eleven-story building from the 1940s (Corona Paredes et al. 2000: 17, 21; Obregón Santacilia 1951:108).<br><br>Features: | 21 large boxes of glass. A selection of one or two objects of each type was made for this study.<br><br>Total artifacts: 49<br><br>Material analyzed:<br>· Bottles<br>· Phials<br>· Tableware (wine glasses, cups, and bowls) | Most of the boxes (19) only contain fragments of dark green wine bottles of different types.<br><br>In some excavation units the material is |

[235] The modern glass includes architectural glass (windows, skylights, and tiles), beer and soft drink containers, and Pyrex™ laboratory glass.
[236] The area excavated was composed of empty lots, some of which were used as parking lots. The excavation area was divided into three sections, one per empty lot. Section 1 corresponded to the south parking lot on the street of Guatemala; Section 2 was located in the Hacienda parking lot; and Section 3 covered an empty lot on street Justo Sierra (Matos Moctezuma 1990: 33-34).

| MEXICO CITY | | | | | |
|---|---|---|---|---|---|
| **Site** | **Location** | **Excavation** | **Archaeological Context** | **Glass Artifacts** | **Notes** |
| | | levels when the layer was too large. | • At the time of excavation the Hotel del Prado had just been demolished and the rubble had been removed. The ground had been flattened to facilitate the access of trucks.<br>• Independent Period: building foundations and basement.<br>• Colonial Period: building foundations, remains of walls, and water wells.<br>• Prehispanic Period: channels on the lake bed related to *chinampas.*[237] (Corona Paredes et al. 2000:93-102). | · Glass production waste (drippings and glass chunks). | predominantly colonial.[238]<br><br>Twentieth century glass was excluded. |
| Bolivia 16 | Lot 16 of street República de Bolivia, in the block between the streets República de Brasil (W), República de Argentina (E), and República de Perú (N). | Excavated as part of a rescue archaeology project (Cedillo and Gudiño 1993).<br><br>Excavation Units: trenches that in some cases were extended, excavated in arbitrary levels. | Stratigraphy: composed of fill layers.<br><br>The site occupied part of a colonial alley and continuous residential occupation since the colonial period until the twentieth century.<br><br>Features:<br>• At the time of excavation, the site was empty and used as a parking lot.<br>• Independent period: a water reservoir, two wells, pipelines, and remains of a wall (Cedillo and Gudiño 1993:16-38).<br>• Colonial period: glazed ceramic pipes, part of a stone paved alley, patio floors, a brick garden plot, walls of 17th and 18th century houses (Cedillo and Gudiño 1993:3-11, 34). | Total artifacts: 100<br><br>Material analyzed:<br>· Bottles<br>· Phials<br>· Buttons<br>· Marbles<br>· Glass production waste (drippings, droplets, trails, rods, chunks of glass, slag)<br>· Small ceramic crucibles with glass residue | |
| Apartado 14, 16, 18/ Nicaragua 55, 59, 61 | The site includes six small lots on streets Apartado (14, 16 and 18) and Nicaragua (55, 59, 61) between | Excavated as part of a rescue archaeology project (Rojas Gaytán and Mena Cruz 2002). | Stratigraphy: composed of secondary deposits resulting from the leveling of the land.<br><br>The site, north of the Acequia[239] del Apartado was used as a paddock in the colonial era and | Total artifacts: 12<br><br>Material analyzed:<br>· Bottles<br>· Phials | Fragments of a phial and a bottle were found inside the colonial artesian well. |

[237] *Chinampas* are garden beds built up from the wetland separated by water canals; the Mexica used them mostly for agriculture (Lombardo de Ruiz 1973: 49).
[238] These include excavation units I, with colonial and prehispanic material; II and IIB, where material from the sixteenth and seventeenth centuries predominates; IIC which also has a mix of prehispanic and colonial material; IIIB, in which there are were eighteenth century water wells containing material from the nineteenth and twentieth centuries; and some colonial material was also found in unit IV which contained mostly prehispanic material (Corona Paredes et al. 2000: 32, 42-43,50, 79, 86).
[239] The term *acequia* refers to a water canal that functioned as a waterway.

| MEXICO CITY | | | | | |
|---|---|---|---|---|---|
| **Site** | **Location** | **Excavation** | **Archaeological Context** | **Glass Artifacts** | **Notes** |
| | the streets República de Argentina (W) and Abraham Castellanos (E). It is located in front of Casa del Apartado. | Excavation Units: test pits that were extended depending on the finds. The excavation was done in arbitrary levels. | later became a residential area (Rojas Gaytán and Mena Cruz 2002:18-22).<br><br>Features:<br>• At the time of excavation lots 14 and 16 of the street Apartado were parking lots; lot 18 had a small office building. Lot 61 of Nicaragua was a parking lot: Lots 55 and 59 had small buildings in poor condition. Prehispanic Period: four postclassic burials and part of a platform.<br>• Independent Period: remains of floors, walls, and pipes dating to the nineteenth century.<br>• Colonial Period: a midden and an artesian well (Rojas Gaytán and Mena Cruz 2002:134-136). | · Production waste (chunks of glass) | |
| Libertad 35 | Located on lot 35 of street Libertad, between streets Jaime Nuno (N), Allende (E), Eje 1 Norte Rayón (S), and Paseo de la Reforma (W) in the neighborhoods of La Lagunilla and Tepito. | Excavated as part of a rescue archaeology project (Sosa Meraz and Morales Sánchez 2002).<br><br>Excavation Units: trenches excavated by layers. | Stratigraphy: composed of six fill layers related to the leveling of the land.<br><br>The site was part of the area where boats arriving to Tlatelolco disembarked in prehispanic times (La Lagunilla) (Lombardo de Ruiz 1973:138). In the colonial period the area had various inns where muleteers spent the night, and eventually became a low-income residential area.<br><br>Features:<br>• At the time of excavation the lot was occupied by small houses dating to the early- and mid-20th century, some warehouses, and a parking lot.<br>• Independent Period: a 19th century midden and the remains of an adobe house dating to *c*. 1900 (Sosa Meraz and Morales Sánchez 2002:3-8, 17). | Total artifacts: 8<br><br>Material analyzed:<br>· Bottles<br>· Phials<br>· Wine bottle seals | The glass artifacts were found in all fill layers except for layer IV which only had prehispanic materials.<br><br>Layer V contained material mostly from the eighteenth century (Sosa Meraz and Morales Sánchez 2002:134-135). |

Unlike Mexico City, Puebla was not built on top of a major prehispanic city, although evidence of a Preclassic village and of ritual activities underneath the modern city have been recovered (Reynoso Ramos 2012:27; 2018:68). However, archaeologists in Puebla have faced similar challenges as those faced by archaeologists in Mexico City. Amongst the shared challenges are the urbanization and modernization programs that in many cases have significantly altered the subsoil and created secondary deposits in the form of construction fills; this means that depending on the occupational history of a particular area, the stratigraphy can be quite complex. Another shared challenge is that most archaeology in the city of Puebla has been done as part of salvage projects, with the limitations that those projects entail.

Compared to the collection of glass from Mexico City, the amount of glass available for study in Puebla was significantly smaller. Archaeologists Citlalli Reynoso and Arnulfo Allende (personal communication, August 2016), who have directed several excavations in the historical downtown of Puebla, comment that glass artifacts have not been particularly abundant in any of the excavations that they have conducted, suggesting that glass was being recycled, kept in use for longer periods, or disposed in a different way than other materials. The uncommonness of glass artifacts in historic sites in Puebla is surprising considering that the city was a major glass production center in the colonial period. Nevertheless, it is also possible that the excavation projects have missed the sites where glassmaking took place.

The archaeological glass from Puebla includes material from five sites: the Museo Amparo, the church of San Juan de Dios, the church of San Roque, the site Huerta del Obispo, and a lot in the neighborhood known as Los Sapos. All the sites are located in the historical downtown of the city and were excavated by archaeologists from Centro Regional INAH Puebla. The archaeological material is kept at the repositories of the Centro Regional INAH Puebla.

The location of the sites can be seen in Figure 63. Brief descriptions of the sites, their stratigraphy, and an overview of the glass recovered are available in Table 4. This is followed by a proposed typology for archaeological glass from Mexico that integrates the material from both Mexico City and Puebla.

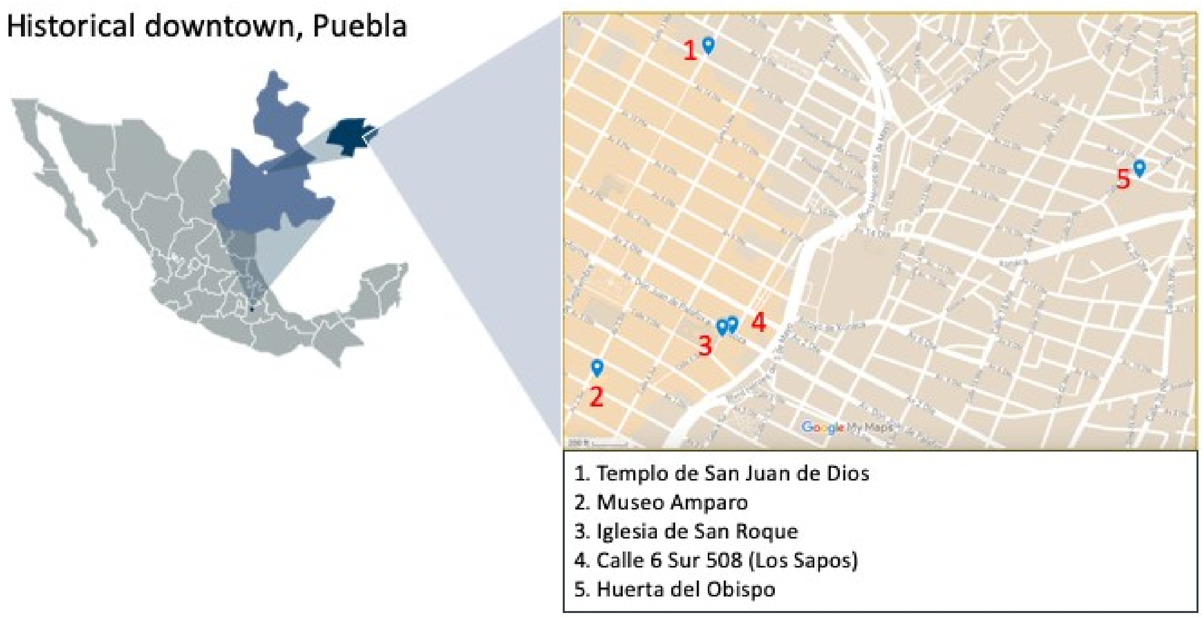


Figure 63. Location of the archaeological sites in Puebla.

Table 4. Descriptions of the sites in Puebla.

| Puebla | | | | | |
|---|---|---|---|---|---|
| **Site** | **Location** | **Excavation** | **Archaeological Context** | **Glass Artifacts** | **Notes** |
| Museo Amparo | In the block delimited by streets 2 Sur, 7 Oriente, 9 Oriente, and 4 Sur. | Excavated as part of a rescue archaeology project (Allende Carrera et al. 2011)<br><br>Excavation units: Test pits and trenches, some of which were extended, excavated in arbitrary levels. | Stratigraphy: composed of three levels: the modern floors, a cement or concrete layer, and a levelling fill. In some areas there was a travertine rock layer. In most units, the bedrock was found at a depth of less than half a meter.<br><br>The museum is housed on the old Hospital San Juan de Letrán or El Hospitalito, established in 1538 (Muriel 1956:150), which in 1691 became a school for girls and in the 18th century a home for women (Leicht 1967:403). In the 19th century, part of the building was divided into residential units. The museum opened in 1991 (Guzmán Gutiérrez 2013:57).<br><br>Features:<br>• At the time of excavation: modern floors and foundations of modern walls.<br>• Independent period: water pipelines, a water reservoir, remains of a fountain, a 19th century midden and six late-19th century burials.<br>• Colonial period: a drainage system made of brick with stone slabs.<br>• Prehispanic period: no evidence reported (Allende Carrera et al. 2011:16-56). | Total artifacts: 9<br><br>Material analyzed:<br>· Table ware (wineglasses)<br>· Phials | The glass artifacts were found as part of secondary deposits in construction fills and the nineteenth century midden.<br><br>The associated ceramics are from the mid-18th to the early-20th century. |
| San Juan de Dios church | In the corner of streets 5 de Mayo and 16 Oriente. | Excavated as part of a rescue archaeology project following an earthquake (Reynoso Ramos 1999).<br><br>Excavation units: | Stratigraphy: Five main layers underneath the modern floor including A: fill; B: sand and silt layer with some travertine; C: fine sand with travertine gravel; D: travertine; E: bedrock.<br><br>The original church dates to 1681. In 1711 it was destroyed by an earthquake and was rebuilt and reopened in 1775. The atrium of the church functioned as a cemetery until the early-19th century (Muriel | Total artifacts: 25<br><br>Material analyzed:<br>· bottles<br>· phials<br>· thin flat glass | Some of the artifacts (fragments of vessels and thin flat glass) were associated with colonial burials dating to the 17th-18th century. |

| Puebla | | | | | |
|---|---|---|---|---|---|
| **Site** | **Location** | **Excavation** | **Archaeological Context** | **Glass Artifacts** | **Notes** |
| | | Trenches, some of which were extended, excavated in arbitrary levels within the natural layers. | 1956:60-61; Reynoso Ramos and Ocaña del Río 2005:60).<br><br>Features:<br>• At the time of excavation: Floor on the atrium made with bricks and stone slabs.<br>• Independent period: a small hole with trash.<br>• Colonial period: foundations of the church tower, a midden, and fifteen primary and secondary burials, including an ossuary.<br>• Prehispanic period: no evidence reported (Reynoso Ramos 1999:28-34). | | |
| San Roque church and hospital | On street Juan de Palafox y Mendoza 607, between streets 6 Sur (west) and Blvd. 5 de Mayo (east).<br><br>The excavation was done on the patio of the ex-Hospital of San Roque, adjacent to the west wall of the church. | Excavated as part of a rescue archaeology project (Reynoso Ramos 2001).<br><br>Excavation units: Square units and trenches excavated in arbitrary levels. | Stratigraphy: composed of ten fill layers related to leveling and the construction of the church. Travertine bits were found in many of the layers.<br><br>The hospital, originally called Hospital de la Caridad de San Hipólito, was built in the 1590s by the brothers of charity. Since 1614 it has been known as Hospital de San Roque. It remained active until 1994. The church dates to 1672 and is still in use (Leicht 1967:355-356; Reynoso Ramos 2001:3-5, 19) .<br><br>Features:<br>• At the time of excavation: modern floor made with stone slabs and cement.<br>• Independent period: brick floor.<br>• Colonial period: mural painting remains on the church wall, stone slab floor, ten primary burials, many secondary burials (cranial remains), and an ossuary.<br>• Prehispanic period: no evidence reported (Reynoso Ramos 2001:19-25). | Total artifacts: 6<br><br>Material analyzed:<br>· bottle<br>· ampoules<br>· inkwell<br>· thin flat glass | The glass artifacts were found in the fills of secondary burials and the ossuary. |
| Huerta del Obispo | Orchard of Casa del Obispo, in street 22 Oriente 1800 in | Excavated by Arnulfo Allende (personal communication April 2019, June | Stratigraphy: surface vegetation, a layer of fertile dirt, and bedrock.<br><br>The building is called Casa del Obispo because between 1808 and 1834 it was the country house of | Total artifacts: 2<br><br>Material analyzed:<br>· wineglass<br>· bottle | |

| Puebla | | | | | |
|---|---|---|---|---|---|
| **Site** | **Location** | **Excavation** | **Archaeological Context** | **Glass Artifacts** | **Notes** |
| | the Barrio de Xonaca. | 2020) as part of a rescue archaeology project.<br><br>Excavation units: test pits excavated in arbitrary levels. | the bishop of Puebla, Pablo Vázquez. He had a large orchard where he planted olives (Leicht 1967:91, 274). The lot remained unoccupied and was used as a sports field. Today it is occupied by a large supermarket.<br><br>Features:<br>• At the time of excavation: grass-covered sports field<br>• Independent period: a 19th century brick water canal covered with stone slabs.<br>• Colonial period: no evidence reported<br>• Prehispanic period: no evidence reported (Arnulfo Allende, personal communication June 2020). | | |
| Los Sapos | On the street 6 Sur No. 508. | Excavated by Arnulfo Allende (personal communication April 2019 and June 2020) as part of a rescue archaeology project.<br><br>Excavation units: test pits, some of which were extended, excavated following the cultural occupation layers. | Stratigraphy: modern pavement and floors, a sandy fill with modern trash, tanning-vats filled with archaeological material, and sterile sands.<br><br>The area has been a plaza since the colonial period, when it had the water canal Acequia del Molino del Carmen which originated in the San Francisco river and attracted toads, hence the name Los Sapos (Allende Carrera 2002; Fernandez de Echeverria y Veitia 1962 [1780]:230; Leicht 1967:441). In the 18th century there was a tannery that closed in 1886 and was adapted as a private residence. Today it is occupied by antique stores.<br><br>Features:<br>• At the time of excavation: modern pavement of stone slabs and concrete floors.<br>• Independent period: six 19th century tanning vats.<br>• Colonial period: no evidence reported.<br>• Prehispanic period: no evidence reported (Arnulfo Allende, personal communication, June 2020). | Total artifacts: 1<br><br>Material analyzed:<br>· bottle | The glass bottle was found inside one of the tanning vats, all of which filled up with trash when the tannery closed in 1886. Most of the material in them dates to the early-19th century. |

### 7.1.2. Typology of Glass from Mexico

The typology proposed here includes material from both Mexico City and Puebla. Although both cities were important production centers in the Colonial period and there may be differences between the products made in each city, the lack of archaeological evidence of undisturbed glass workshops in either city hinders the assignation of provenance with absolute certainty, which would be necessary for a more localized typology to be proposed. Moreover, the small size of the collection from Puebla and the lack of production waste from this city did not allow for the establishment of a reliable local typology.

The guidelines and methods followed to classify the material are described in Chapter 4. This typology only includes representative examples of each category. Most of the material presented here corresponds to the eighteenth and nineteenth centuries. Industrial glass was not considered. This typology is only based on materials analyzed during this research and therefore, it should not be considered exhaustive. A larger variety of glass artifacts from the one presented here should be expected. Further studies of archaeological glass collections will be needed to refine and add on to this typology. It should also be noted that a broad category of “Imported Glass” is included that presents artifacts dating between the late-eighteenth and the early twentieth century from different parts of Europe and the USA. These artifacts have characteristics that clearly indicate that they were imported into New Spain, and after 1821 Mexico.

#### 7.1.2.1. Glass Production Waste

Glass production waste was found only in the collections from Mexico City, specifically from the sites Templo Mayor, Bolivia 16, and Apartado/Nicaragua. The artifacts in this category include leftover glass chunks, droplets, trails, fragments of crucibles, kiln waste, and rods. In addition, small ceramic crucibles with spouted rims, some of which have glass residue inside, are included in this section given that, most probably, they were related to glassworking.

<u>Chunks of glass</u>

These usually represent a glass batch that cooled down rapidly in an uncontrolled manner (outside of an annealing chamber). Depending on the setting, they can represent raw glass that will later be re-melted for glassworking or leftover glass from a crucible, or from the dismantling of a furnace. The latter is commonly found today in artisanal glass workshops in Jalisco that have tank furnaces (Figure 64). Because the cooling occurs rapidly, the glass does not have time to release the stresses that occur as its temperature decreases and tends to crack as it solidifies. For this reason, the chunks of glass usually present sharp, angled edges. They vary in size depending on the size of the batch. In some cases, the glass can present streaks of different colors (*e.g.*, TM-236), which could be attributed to incomplete mixing while preparing colored glass, recycling of glass of similar colors, or contamination of a color batch.[240] The collections revised included 46 chunks of green, aquamarine, yellow/amber, colorless with a yellow tint, and opaque red glass (Figure 65).

[240] Colored glass is usually kept in separate crucibles in a furnace. However, any glass in a firing furnace looks bright orange regardless of its actual color. Glass artisans need to remember the location of each color in the furnace to avoid mixing them or gathering the wrong color.

Figure 64. Chunks of leftover glass from workshops in Jalisco (photos: Karime Castillo).

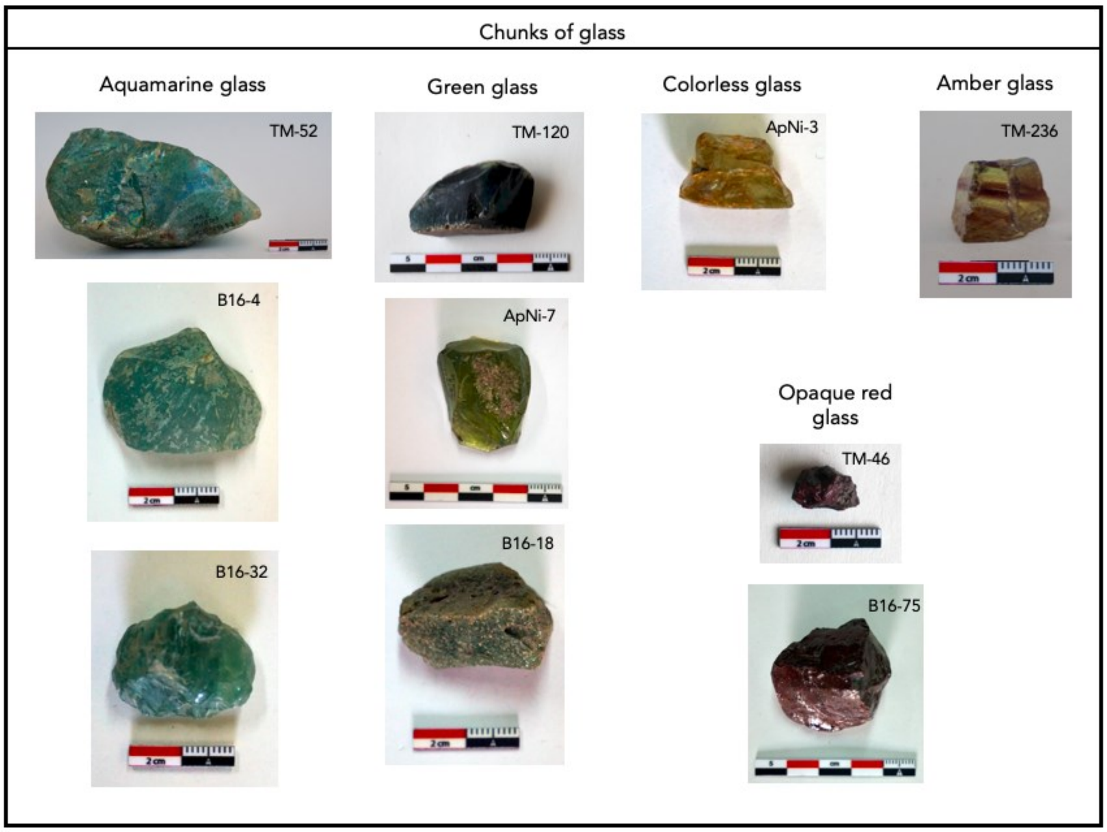


Figure 65. Examples of chunks of glass of different colors (photos: Karime Castillo).

<u>Droplets</u>

Small droplets of glass sometimes fall around the furnace during glassworking (Figure 66). They tend to be small (1-2 $cm^3$), have rounded shapes, and sometimes present a break when they were originally part of a thread or dripping (*e.g.*, B16-11, B16-12). In the collections studied, there are nine droplets of green and aquamarine glass (Figure 67).

Figure 66. Droplets, drippings, and threads of glass dropped during glassworking in a workshop in Jalisco (photo: Karime Castillo).

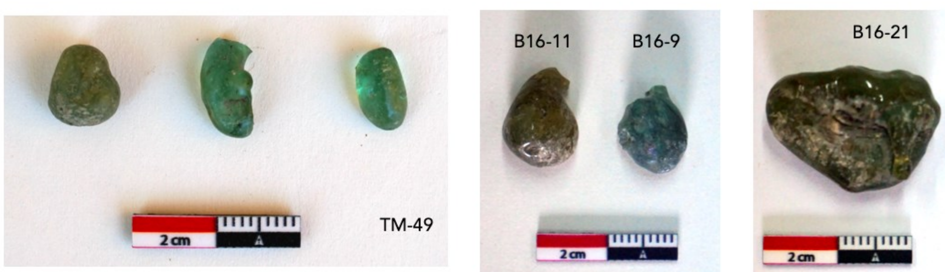


Figure 67. Examples of aquamarine and green glass droplets (photos: Karime Castillo).

<u>Trails</u>

Trails and drippings of glass can be discarded as part of glassworking, for instance, when attachments are added to an object. In this process, a gather of glass is stuck to the object, stretched out to a desired thickness, and cut off at an appropriate length. The trail of leftover glass on the tool is then discarded (Figure 68). Large trails are usually recycled, but the small ones can end up trampled into the floor (Paynter and Dungworth 2011a:19). Trails tend to have elongated irregular shapes but can sometimes get folded; they vary in size and thickness. In the collections from Mexico there are twelve trails of green, dark green, aquamarine, and colorless glass with a yellowish tint Figure 69.

Figure 68. Disposal of excess glass (photo: Karime Castillo).

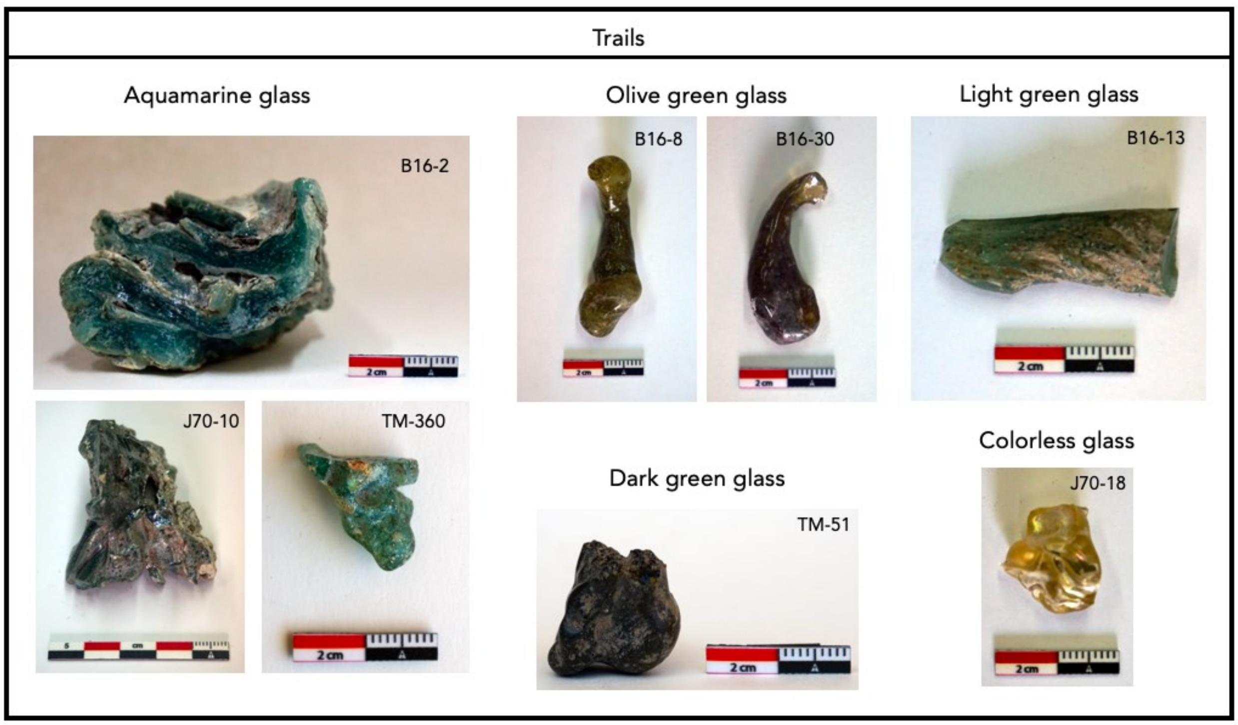


Figure 69. Trails and drippings of glass of different colors (photos: Karime Castillo).

<u>Rods</u>

Thin cylindrical rods of glass of different colors for lampworking were made by stretching a gather of glass into a very long tube which was cut into rods as seen in the sequence in Figure 70. These rods were sold to lampworkers who use them as raw material to make beads and other small objects (

Figure 71).

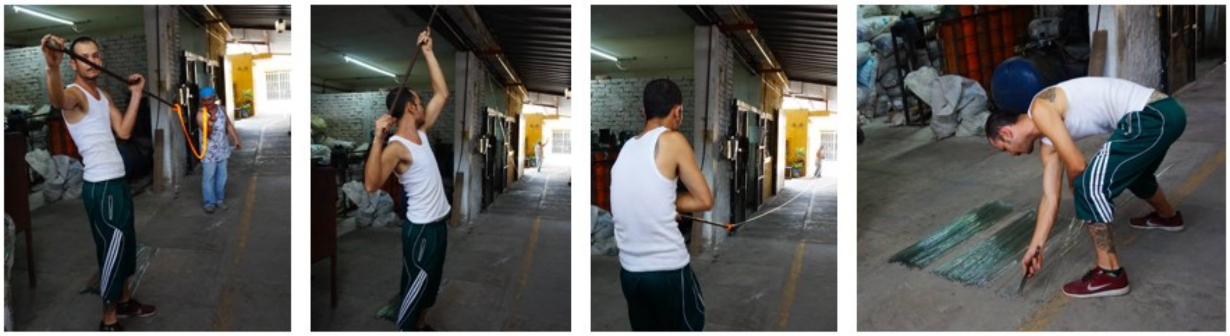

Figure 70. Two glassmakers stretching glass into rods in Jalisco (photo: Karime Castillo).

Figure 71. Lampworker[241] in Jalisco working with glass rods to make small glass figures (photo: Karime Castillo).

[241] Lampworkers today use blowtorches instead of flames as a source of heat.

The collections revised included 265 rod fragments in different colors including green, light and dark blue, yellow, amber, purple, and black (Figure 72). All of them were recovered from the site Bolivia 16 and may indicate that lampworking was done at the site.

Figure 72. Examples of glass rods of different colors from the site Bolivia 16 (photos: Karime Castillo).

<u>Furnace or kiln waste</u>

Because of the high temperatures required for glassworking, furnaces have a limited lifespan. Furnaces in traditional glassblowing workshops in Mexico, for instance, need to be replaced every four to six years, and it is common to find remains of dismantled furnaces in the vicinity of a glass workshop (Figure 73a). Furnace waste includes remains of glass furnaces such as refractory bricks, which usually show vitrification or spilled glass on a side (Figure 73b); fragments of gathering hole[242] covers, which also tend to show more exposure to heat on one side (Figure 73c); as well as glass that fell into the combustion chamber, which depending on the fuel used, may have pieces of charcoal attached to it. Furnace waste in the collection under study

[242] A gathering hole or glory hole is the opening in the furnace that allows access to the glass melt. It is often also used to reheat an object for further shaping.

includes fragments of furnace walls, including a waste piece with charcoal attached to it (TM-182), and glass that may have fallen into the combustion chamber (Figure 74).


Figure 73. Waste from modern furnaces in Jalisco, Mexico: a) pile of bricks from a dismantled furnace; b) tank furnace bricks with remain of glass; c) fragment of a gathering hole cover showing deterioration on the side exposed to the heat (photos: Karime Castillo).


Figure 74. Fragments of archaeological glass furnace waste (photos: Karime Castillo).

Ceramic crucibles

Crucibles can be defined as free-standing vessels used for operations conducted at high temperatures (Martinón-Torres and Rehren 2009:49), and in the glass industry they are used to hold molten glass inside a furnace. Crucibles for glass, also called pots, are usually made of refractory ceramic, and tend to be large and sturdy but they can vary in size and shape. Most crucibles are shaped like bowls or buckets (Figure 75a, 9b, 9d), but in the nineteenth century standing crucibles, close to 1.5 m tall, were used in Europe (Figure 75c) (Paynter and Dungworth 2011a:18). While modern furnaces have large tanks full of molten glass, bowl-shaped crucibles that float on top of the melt are still used to keep glass of different colors separate (Figure 75d). Used crucibles usually have leftover glass inside them and many show a glassy coating on the outer surface caused by the reactions of the ceramic with the corrosive furnace atmosphere (Paynter and Dungworth 2011a:17-18). The glassy layer on those that float in modern tank furnaces will be thicker and accumulated on the bottom of the outer surface (Figure 75d).

The glass collections studied include several fragments of crucibles with blue-green and dark red glass from the sites Bolivia 16 and Templo Mayor (Figure 76). In addition, there are smaller crucibles, sometimes known as "piling pots," that were used to test glass color preparations or to hold colored glass needed in small amounts and were set on top of larger crucibles (Paynter and Dungworth 2011a:18). These small crucibles could have also been used for lampworking. Examples of such small crucibles were found at the site Bolivia 16 (Figure 77a) and a small fragment at Templo Mayor in Mexico City. The crucibles are hand-modeled, have rounded bases, straight irregular walls, direct rims, and a pinched spout (Figure 77a, 16b). Some of them have a vitrified exterior and residues of opaque red glass inside (Figure 77c, 16d).

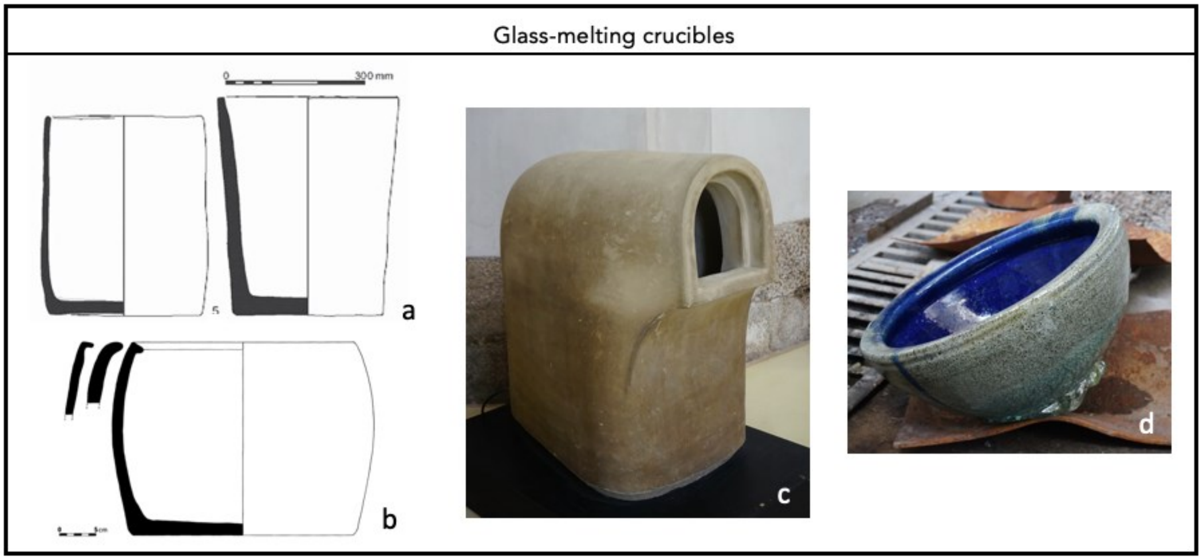


Figure 75. Examples of glass-melting crucibles: a) seventeenth-century crucibles from England (Paynter and Dungworth 2011a:18, Fig. 26, detail); b) seventeenth-century crucible from Belgium (Terlinden and Crossley 1981:198, Fig. 6); c) nineteenth-century standing crucible, Real Fábrica de Cristales de La Granja, Spain (photo: Karime Castillo); d) modern crucible from Jalisco, México containing leftover blue glass and showing a residue of colorless glass on the outer surface from floating on the melt (photo: Karime Castillo).


Figure 76. Fragments of crucibles with red and blue-green glass (photos: Karime Castillo).

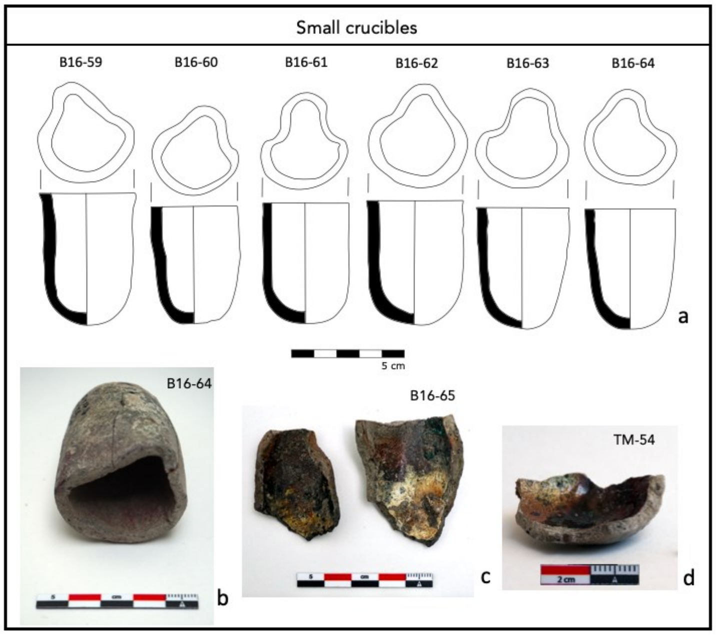


Figure 77. Small crucibles or piling pots: a) set of six hand-modeled crucibles; b) crucible showing the spouted rim; c) interior of crucible fragments with remains of dark red glass; d) base of a small crucible with remains of dark red glass (photos and drawings: Karime Castillo).

7.1.2.2. Free-Blown Glass

This category includes blown glass objects shaped without the aid of molds. Glass artisans use a marver to shape the glass blob as they blow it, and they use jacks and pincers to manipulate the glass into the desired form. Free-blown objects are usually not perfectly symmetrical and can present a lot of variations in their features, for instance, in the angle and size of the rims, or in height and width. Artisans might use measuring tools to achieve a certain level of standardization if needed, but free-blown glass objects of the same type tend to have slight differences amongst them. The free-blown glass objects in the collections studied are represented primarily by containers, more specifically bottles and phials.

<u>Containers</u>

Bottles

The collections from both Mexico City include fragments of free-blown bottles in colorless and blue glass, most of them have cylindrical bodies (Figure 78 right) but in some cases they can have a globular or tapered shape (Figure 78 left). Free-blown bottles are shaped by rolling them on a marver and perfected with tools, as can be seen on Figure 79.

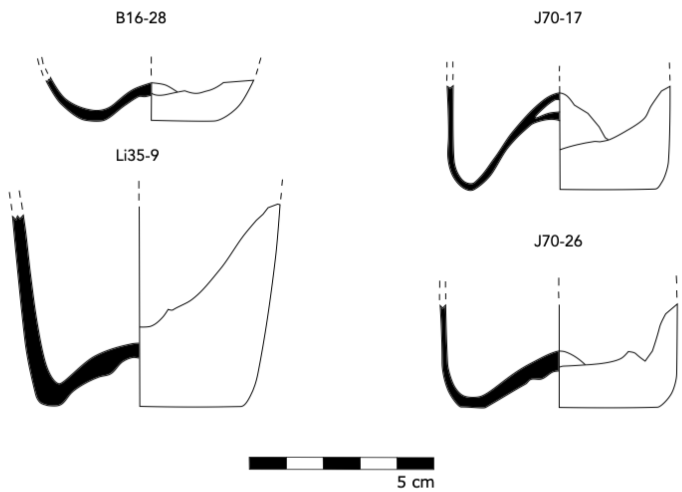


Figure 78. Free-blown bottles found in Mexico City (drawings: Karime Castillo).

Figure 79. Glassblower in Jalisco making a free-blown bottle (photos: Karime Castillo).

Dark green wine bottles

Fragments of dark green wine bottles were recovered from the sites Juárez 70, Apartado/Nicaragua, and Templo Mayor in Mexico City as well as from San Juan de Dios in Puebla. As mentioned before, the site Juárez 70 yielded a considerable amount of wine bottles of different kinds and given the large amount of remains, a selection of representative examples was made. Among the selected artifacts there are seventeen fragments of free-blown wine bottles made with dark green glass. The bottles are cylindrical in shape, with uneven walls, and a deep kick-up base (Figure 80).

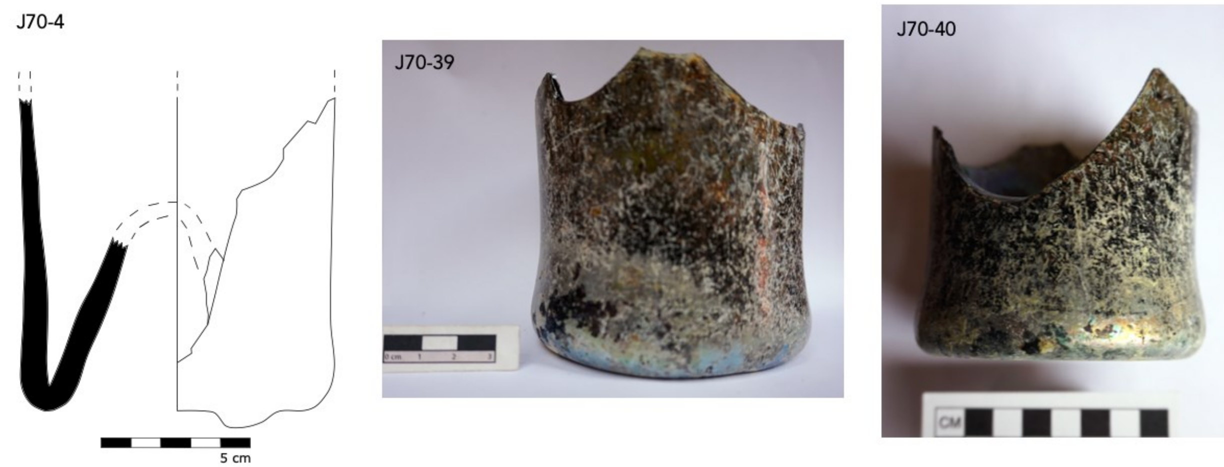


Figure 80. Free-blown bottles found in the site Juárez 70 in Mexico City (photos and drawing: Karime Castillo).

Phials

Phials are small vessels with insufficient capacity to have held comestibles and are usually employed to hold liquids. Most of them were probably employed to hold valuable liquids such as perfumes or medicines (Willmott 2002:89). In the collections of Mexico City and Puebla the majority of the free-blown phials have cylindrical bodies and kick-up bases. The top fragments in the collections vary, they can have long or short necks, the rim can be wide or narrow and can be direct (Figure 81e), slightly everted (Figure 81a), everted (Figure 81d), horizontal (Figure 81b), or rolled (Figure 81c).

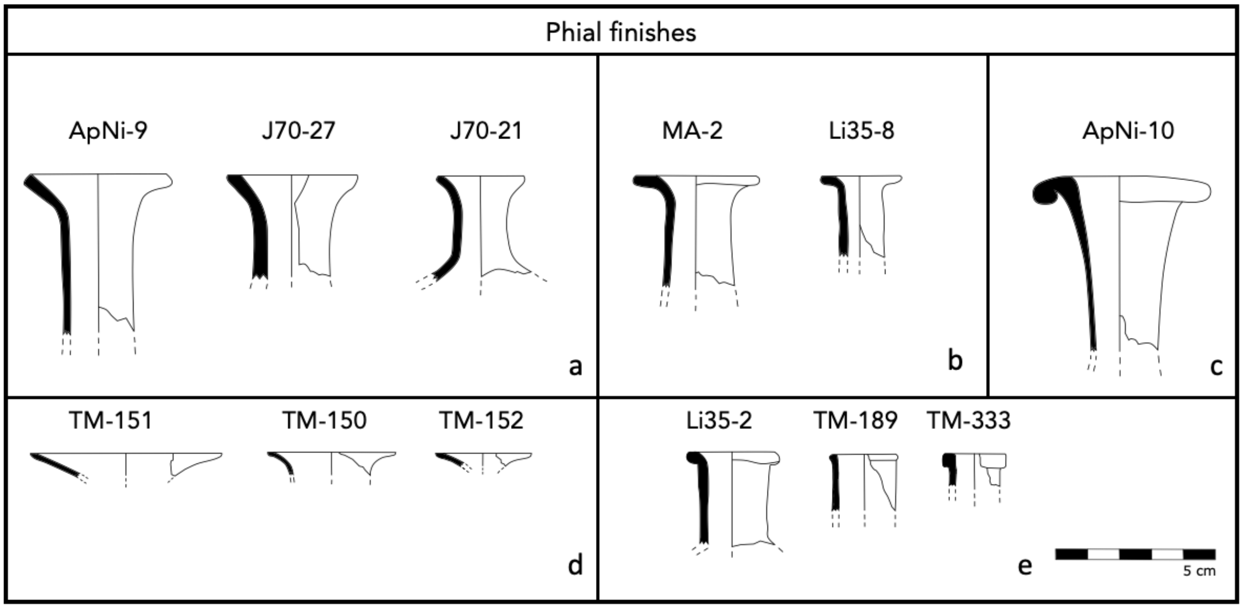


Figure 81. Phial finishes: a) slightly everted rim and long neck; b) horizontal rim and long neck; c) rolled rim and long neck; d) everted rim; e) direct rim and thickened lip (drawings: Karime Castillo).

Tableware

Stemware

Stemware examples, fragments of wine glasses in particular, are present in the collections of Mexico City and Puebla. All of them are made of colorless glass. The most complete example, which may represent an example of cut glass, has a bucket-shaped faceted bowl, an angular knop at the center of the stem, and a conical foot (Figure 82 right). The lower fragments of two other wine glasses also have conical foots and one of them has an angular knop on the stem (Figure 82 left). There is also a fragment of a twisted stem (Figure 82 center).

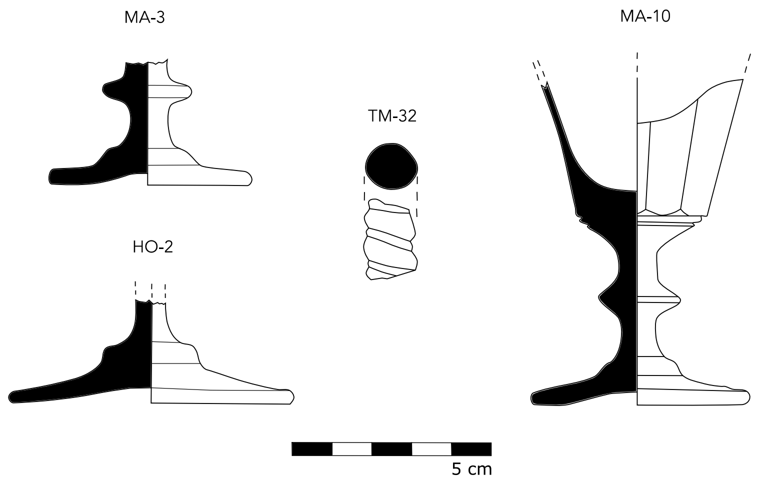


Figure 82. Stemware found in Mexico City and Puebla (drawings: Karime Castillo).

### 7.1.2.3. Stretched Glass

Some glass objects, ornaments and attachments in particular, are made by manipulating the glass using tools like jacks and pincers into particular shapes without any blowing involved. Decorative figures and attachments such as handles for vessels and bases of stemware are made this way in the workshops of Jalisco and Puebla (Figure 83).

Figure 83. Glass artisans in Jalisco attaching a handle to a jug (left) and in Puebla manipulating a figure (right) (photos: Karime Castillo).

Stretched glass artifacts in the collections are represented by attachments that broke off from an object, in this case, two colorless glass handles from jugs, one twisted, and one plain (Figure 84).


Figure 84. Examples of twisted (left) and plain (right) stretched glass handles (photos: Karime Castillo).

7.1.2.4. Mold-Blown Glass

This category includes glass artifacts that were partially or fully blown into shape with the aid of molds. Single piece molds, also called dip-molds, were used to make bottles until the early nineteenth century. These molds shaped the lower part of the bottle while the shoulder, neck, and finish were done by hand (Jones and Sullivan 1989:24-26). In the mid-eighteenth century, hinged two-part molds that could be quickly opened and closed were introduced. Bottles made in two-part molds usually have seam marks on the sides. Hinged molds allowed for the neck and shoulder of bottles to also be formed in the mold, but they still required the finish to be formed as a separate step (Jones and Sullivan 1989:26-27). In some cases, the bottle was simply cracked off without further treatment. A snap clip was also invented that eliminated the need for the pontil and left no mark on the base (Douglas and Frank 1972:165). Mold-blowing also allowed for texts and marks to be embossed on the glass. Embossing became widely used in the making of bottles for patent medicines, which were very popular during the late eighteenth and nineteenth centuries (Douglas and Frank 1972:172). Glass blown into molds in the collections revised include cylindrical wine bottles, squared-section bottles, phials, patent medicine bottles with embossed labels.

<u>Containers</u>

Phials

Fragments of cylindrical phials that were probably blown into dip-molds are present in the collections from Mexico City. They have regular bodies and very shallow kick-up bases (Figure 85). A nearly complete example showing these characteristics from the site Apartado/Nicaragua has slightly sloping shoulders, a short neck and a narrow slightly everted rim (Figure 85 far right), however the finishes on other phials might have differed.

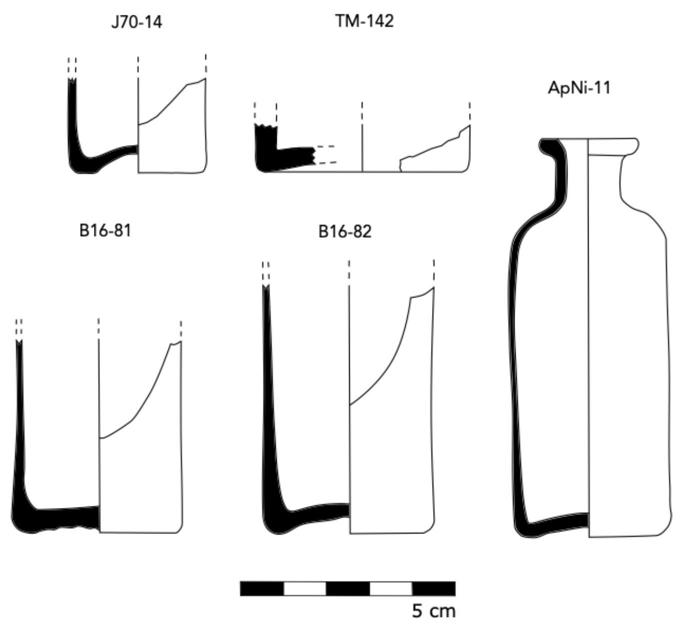

Figure 85. Examples of mold-blown cylindrical phials (drawings: Karime Castillo).

Other phials were blown into molds designed to impart a texture or pattern to the vessel, such as vertical ribs. In some cases, the glass artisan would twist the glass to produce diagonal or spiral patterns. Molds of this type and the twisting technique are used by glass artisans in Jalisco and Puebla today (Figure 86). Examples of phials made in this way are present in the material from Templo Mayor, Apartado/Nicaragua, and Bolivia 16 in Mexico City, as well as in the collection from Museo Amparo in Puebla. These phials are made of aquamarine and colorless glass, have slightly everted rims and short necks; the grooves can run vertically or diagonally (Figure 87).

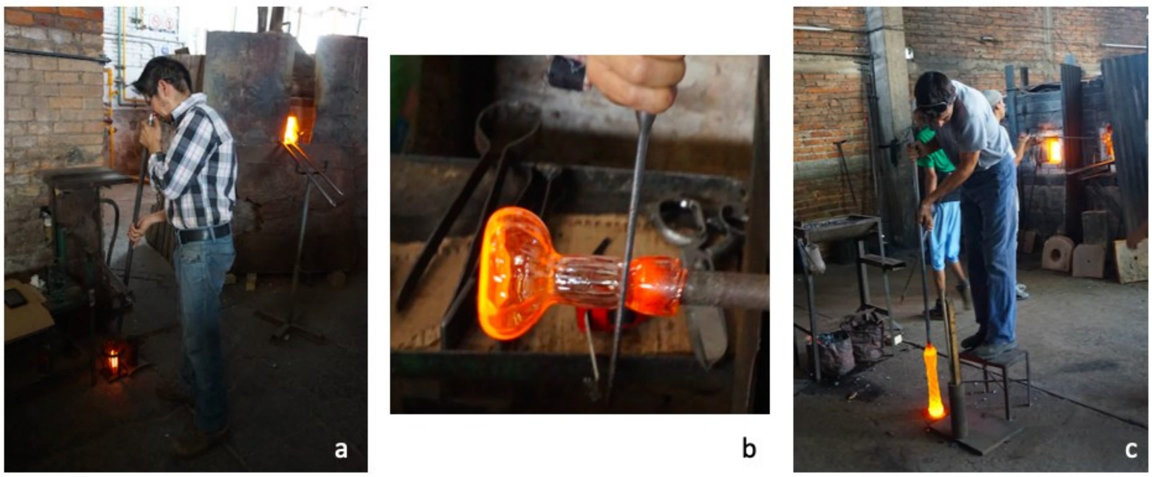


Figure 86. Glassblowers in Puebla and Jalisco using molds to create texture: a) artisan blowing glass into a texturizing mold in Puebla; b) ribbed blown vessel after shaping; c) artisan twisting a ribbed vessel in Jalisco (photos: Karime Castillo).

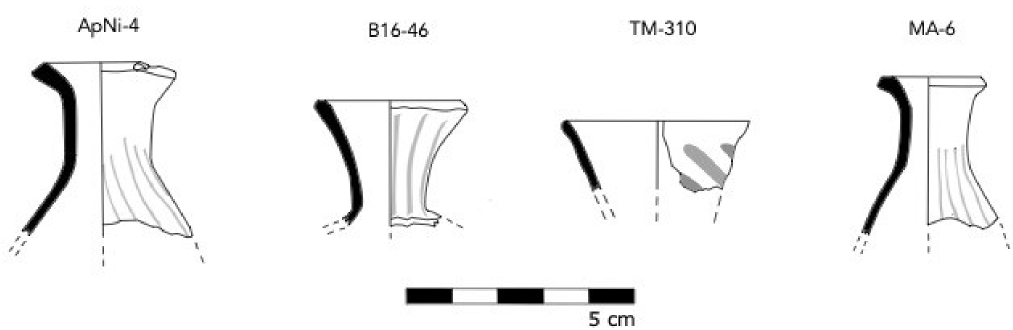


Figure 87. Ribbed phials found in Mexico City and Puebla (Drawings: Karime Castillo).

## Wine and liqueur bottles

Depending on the type of mold used to make mold-blown wine bottles, they may have no seam, a lateral seam (if made in a two-part mold), or more seams if a mold of three or more parts was used. Mold-blown bottles were usually finished manually or by using specialized tools designed to produce standardized finishes.

Dip-molded bottles

Dip-molds (sometimes called one-piece molds) are used to shape the body and sometimes the base of bottles, by blowing the glass inside them, but the shoulder, neck, and finish are shaped by hand-tooling (Jones and Sullivan 1989:24-26). This type of mold is still in use in Jalisco to make objects like shot and drinking glasses of the same diameter (Figure 88). Some of the blown bottles with symmetrical and standardized bodies in the collections examined may have been made with the aid of this type of mold. While any skilled glassblower can certainly produce symmetrical and standardize pieces with the help of measuring tools, using a mold will significantly speed up the process.

Figure 88. Glassmaker in Jalisco using a dip-mold to make a shot glass (photo: Karime Castillo).

Cylindrical wine bottles, which initially had a squat appearance, began to appear in Europe in the early eighteenth century, and according to Dungworth (2012:39), the majority were made in molds, which initially were of the dip-mold kind. This type of mold remained in use for bottle making until the mid-nineteenth century despite later developments in bottle molds. Four wine bottles in the Mexico City collections from the sites Juárez 70 and Bolivia 16 were made using this type of molds (Figure 89). They have regular cylindrical bodies, which in some cases can be slightly tapered, and a kick-up base with a fairly regular shape (Figure 89 right).

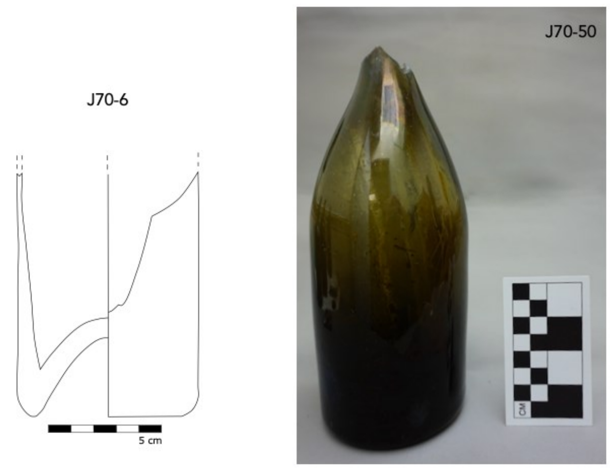

Figure 89. Mold-blown wine bottles from the site Juárez 70 in Mexico City (photo: Karime Castillo).

Squared-section bottles (gin/case bottles)

A particular type of dip-molded bottle is the squared-section bottle, also known as case bottle because the shaped allowed for efficient packing in cases. They tend to tapper inwards towards the bottom and have a very short neck (Jones and Sullivan 1989:72). This type of molded, flat sided bottles originated in Europe, appearing in Germany since the late sixteenth century and in other parts of Europe throughout the seventeenth century. Case bottles were commonly used by apothecaries in the seventeenth and eighteenth centuries, ultimately becoming associated with gin, which was originally dispensed as a medicine. Case bottles of the seventeenth century were almost straight-sided and became progressively narrower at the base towards the end of the eighteenth century (McNulty 1971:103, 107; Munsey 1970:84). Most case gin bottles were made in dark colors and they can occasionally have shoulder seals. Those made in the nineteenth century are sometimes embossed (Munsey 1970:85). Two examples of case gin bottles from the site Juárez 70 were included in this study, one in green glass with a shallow kick-up base, and another one in dark amber glass with thick walls and a more pronounced kick-up base (Figure 90).

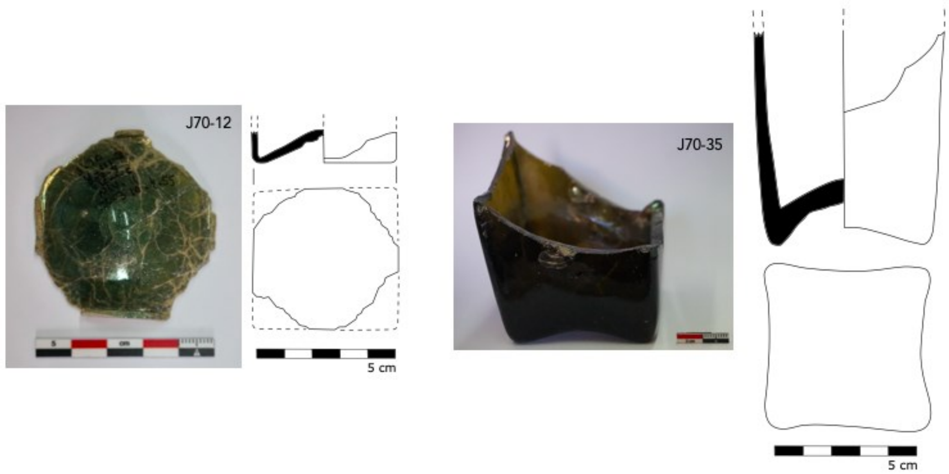


Figure 90. Case gin bottles from the site Juárez 70 in Mexico City (photos and drawings: Karime Castillo).

Two-piece mold bottles

Two-piece molds have hinges at the side or bottom that allow for the mold to be open and closed. This makes it possible to form the base, body, shoulder, and neck of a bottle in a single operation, but the finish is done manually. Objects made in this type of molds usually show seam marks indicating the joints of the mold (Jones and Sullivan 1989:26). Hinged molds allowed for the production of bottles with taller bodies and for the quick production of bottles of uniform size, although capacity could vary depending on the amount of glass used (Dungworth 2012:39-40). Different types of hinged molds exist, some of them require two people to operate them, one that opens and closes the mold and one glassblower. Other types have levers to open and close them that are activated with a push of the foot that can be operated by a single person. Some of the bottles for tequila are today made in Jalisco using two-piece molds operated by one or two artisans (Figure 91).

Figure 91. Artisans in Jalisco making a bottle using a two piece mold (photo: Karime Castillo).

Three (or more)-piece mold bottles

During the nineteenth century, more varieties of hinged molds were developed that consisted of three or more parts. Patents for different types of hinged molds begin to appear in the 1820s. One of the them was the Ricketts three-piece mold, which consisted of a dip-mold, two matching top halves that shaped the shoulder and neck, and occasionally, a separate base plate that was used to emboss the bases of bottles. This type of mold left a horizontal seam at the top of the body and side seams on the shoulder and neck of the bottle. While the Ricketts mold was patented in 1821, this type of mold and variants of it remained in use until the 1920s (Dungworth 2012:39-40; Jones and Sullivan 1989:28-29). The material studied, particularly from the site Juárez 70, includes many fragments of bottles that may have been made with three-piece molds of the Ricketts type, some of which present embossed bases and are discussed below in the imported glass section.

Bottle Finishes

Bottle finishes also changed in the nineteenth century. Ring or collar finishes made by a thread of additional glass to the top of the bottle (applied finish) allowed for the cork to be tied to the bottle to prevent the pressure caused by fermentation from popping it and variations of them were common throughout the nineteenth century. Later in the century uniform finishes were achieved by using a special pair of tongs that allowed the shaping of a uniform finish of a particular shape (Figure 92). The tool was applied while rotating the bottle after reheating it and did not require the addition of extra glass for the finish. The resulting bottle finish is known as a tooled finish (Douglas and Frank 1972:168; Dungworth 2012:40; Lindsey 2016:309).

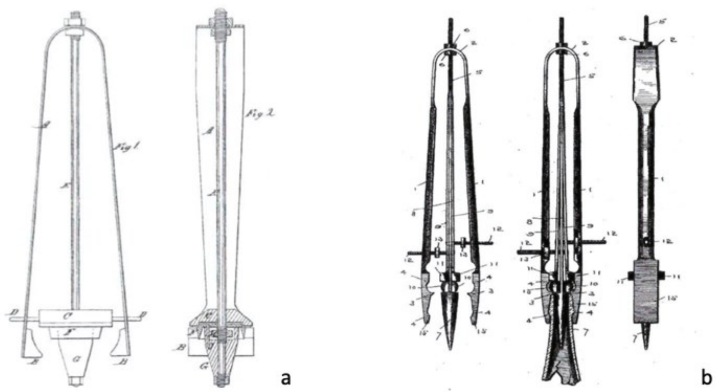


Figure 92. Examples of finishing tools: a) finishing tool patented in 1856 (Lindsey 2016:305, Figure 313); b) finishing tool patented in 1893 (Lindsey 2016:311, Figure 319).

Applied Bottle finishes

Only one fragment of a bottle top, from the site Juárez 70, displays an applied finish consisting of a flattened string rim of irregular shape (Figure 93). This type of finish is also known as the Champagne type and began to be used in the eighteenth century (Jones and Sullivan 1989:79).

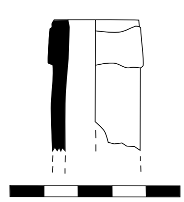


Figure 93. Applied finish of a bottle of the Champagne type (drawing: Karime Castillo).

Tooled Bottle Finishes

Two types of tooled finishes are present in the collections from Mexico City. Both of them correspond to double ring finishes but in one case the rings are V-shaped (Figure 94a) and in the other (Figure 94b) the rings are rounded (Jones and Sullivan 1989:96). While the necks of the bottles in both cases are long, the bottles with the rounded tool finishes have a bulged neck.

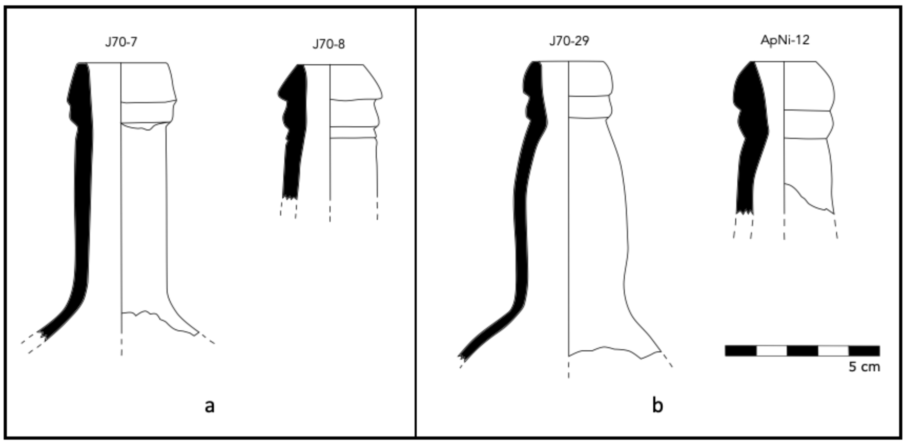


Figure 94. Tooled bottle finishes: a) V-shaped double ring; b) rounded double ring (drawings: Karime Castillo).

7.1.2.4. Pressed Glass

Mechanical presses were invented in the US, initially for the pressing of furniture knobs, and appeared on a small scale in 1825. By 1830, presses for flat and hollow ware had been developed. Mass-produced pressed glass that provided a cheap alternative to expensive cut lead crystal began to be exported to Europe and the rest of the Americas. The press requires a person to gather a specific amount of glass that is poured into the mold while another person shears off the gather and operates the lever that lowers the plunger into the mold. Too much glass results in objects that are too thick, while too little glass renders incomplete pieces. Pressed glass can be identified by the seams left by the mold joints. Unlike the smooth surface of blown glass, the surface of pressed glass tends to present small interstices (Douglas and Frank 1972:37; Tait

2004:197-198). Pressed glass, which was very popular in Mexico in the early twentieth century, has been recently revived in Puebla at the Antigua Fábrica de Vidrio La Luz. A press mold and two finished pressed glass objects, a cup[243] and a jug, can be seen in Figure 95. Two plungers for pressing the glass are visible to the right of the finished jug.

Figure 95. Mold for making a pressed glass vase with elaborate decoration (left) and two finished pressed glass objects, a cup and a jug (right) (photos: Karime Castillo).

The collection from Apartado/Nicaragua includes a fragment of the top of a pressed candy jar cover with a rounded finial elaborately decorated with alternating crisscrossed panels and vertical bands, and a cross at the tip. The top appears to have been decorated with thin concentric steps (Figure 96).


Figure 96. Fragment of a pressed candy jar cover (photos: Karime Castillo).

[243] The cup is popularly known as *cacariza* and it was traditionally used in *pulquerías* to serve *pulque*, a fermented, mildly alcoholic beverage made of the sap of agave plants (Kepecs et al. 2018: 31-32, 39).

Flatware

The collection includes a few examples of pressed flatware, mainly dishes, from the site Templo Mayor in Mexico City. All eight dish fragments are made of white opaque glass. The rim fragments are all direct although some of them are slightly curved, and the base fragments are annular. Some of the fragments have painted decoration including three rims with a gold-yellow band on the lip, and one rim with green linear designs (Figure 97). Seam marks can be seen on two of the bases.

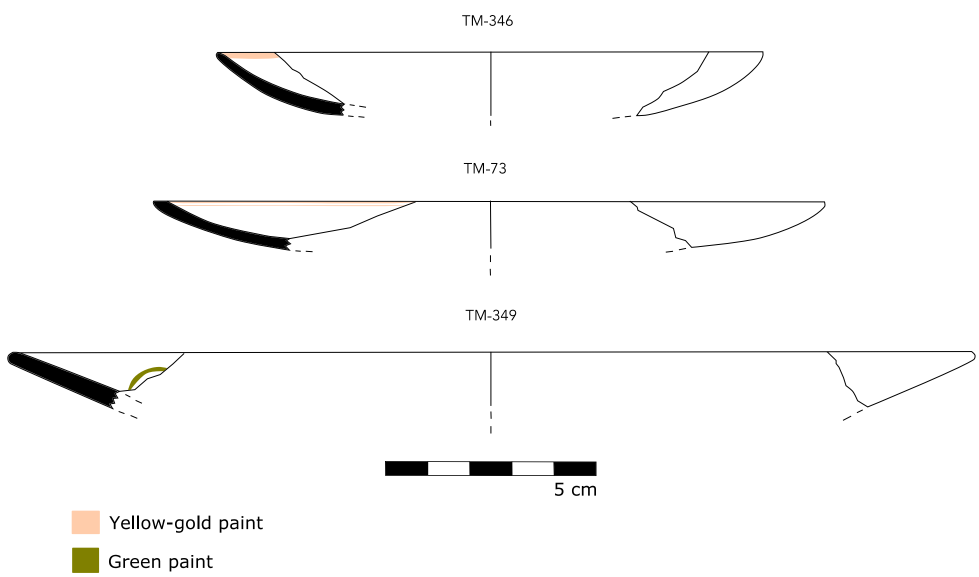


Figure 97. Examples of opaque white glass dishes with painted decoration (Drawings: Karime Castillo).

7.1.2.5. Machine-blown

In the mid-nineteenth century, several attempts were made to develop faster and more efficient methods to make glass bottles and other containers. One of the first patents for a bottle making machine was awarded in 1859 to Alexander Mein of Glasgow and was followed by other inventions in both Britain and the United States. In 1886 Howard Ashley got a patent in England for a "press-and-blow" machine which incorporated the pressing method to crudely shape the object and compressed air to inflate the glass. The whole process could be done by a single person and greatly increased the speed and volume of production. Similar machine designs made in the United States, Britain, France, and Germany followed, but they all required the glass to be fed manually to the machine so they are known as semi-automatic (Douglas and Frank 1972:41, 173-179; Dungworth 2012:40; Miller and Sullivan 1984:85). Semi-automatic machines are used in workshops in Jalisco today, where they are called “guajolotas” (Figure 98), primarily for the production of tequila bottles.

Figure 98. Glass artisans in Jalisco operating a semi-automatic bottle-making machine.

The first fully automatic glass-forming machine was the Owens bottle machine, which takes the glass through vacuum suction and formed the bottle in a mold using compressed air. It was developed in the last decade of the nineteenth century and patented in 1903. This machine required no skilled labor for operation and produced twenty uniform bottles per minute (Douglas and Frank 1972:41-42, 182-183; Dungworth 2012:40-41; Miller and Sullivan 1984:85). In 1932, a new type of bottle machine was patented known as Individual Section (IS) machine which used the same forming techniques as Owens machines, but allowed for the moving parts to be removed, facilitating maintenance without stopping production. This model came to dominate the bottle-making industry from the 1950s onward (Douglas and Frank 1972:189-191; Dungworth 2012:41).

Machine-blown bottles, whether made with semi-automatic or fully automatic methods, tend to have seams, embossing, or valve marks on the base; lateral seams on the body that extend through the finish and reach the lip; as well as additional horizontal seams on the finish (Miller and Sullivan 1984:93).

Screw-top bottles

The screw finish appeared for the first time in the late nineteenth century. Initially, the screw was placed on the inside of the rim and used a threaded cork. The external thread was developed in the nineteenth century and the cork was replaced by a metal screw cap (Dungworth 2012:41). The material from the site San Roque includes a dark amber bottle with a screw finish, short neck, rounded-sloping shoulders and a cylindrical body with lateral seam marks that continue through the finish and reach the lip indicating machine manufacture. The finish retains parts of the now corroded metal cap (Figure 99). This object probably represents a pharmaceutical bottle. The dark amber color helped protect the contents from the light, which was necessary to avoid the degradation of some medicines (Schaut and Weeks 2017:281).

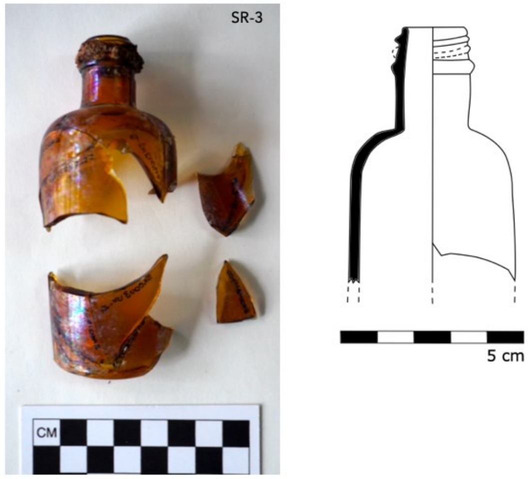


Figure 99. Screw-top medicine bottle (photo and drawing: Karime Castillo).

Ampoules

Ampoules are small containers designed to hold small amounts of liquids or powders that are sealed off after filling. The contents can be easily accessed by breaking one end of the ampule, for this reason, many ampules have narrow necks that facilitate their opening, but their shape and size can vary. Ampules are manufactured in automatic machines with thin-walled glass tubing (Douglas and Frank 1972:173). The material from the San Roque site in Puebla includes two small cylindrical ampoules with narrow necks, one of dark amber glass with a slim body (Figure 100 left) and the other one with a squat body made of amber glass (Figure 100 right).


Figure 100. Examples of glass ampoules from Puebla (photo: Karime Castillo).

Inkwells

Inkwells are containers for ink from which a quill or fountain pen could be loaded with ink by dipping (Munsey 1970:120). Inkwells differ from ink bottles in their shape, more specifically in their finish, which in inkwells is inverted (turned inwards) and in some cases can form a sort of funnel; inkwells were also considered decorative elements and were relatively expensive items so they were meant to be constantly refilled. In contrast, ink bottles have more traditional bottle finishes, were usually sold full of ink, and were of a more disposable nature (Munsey 1970:120; Nickell 2000:45). The collection from San Roque includes a complete mold-blown inkwell of cylindrical shape that is slightly wider towards the top (Figure 101). The whole body is decorated with spiraling horizontal groves. The base is flat and has a mark of concentric circles. The rim is turned inwards forming a funnel. Faint seam lines can be seen on the top and bottom of the inkwell.

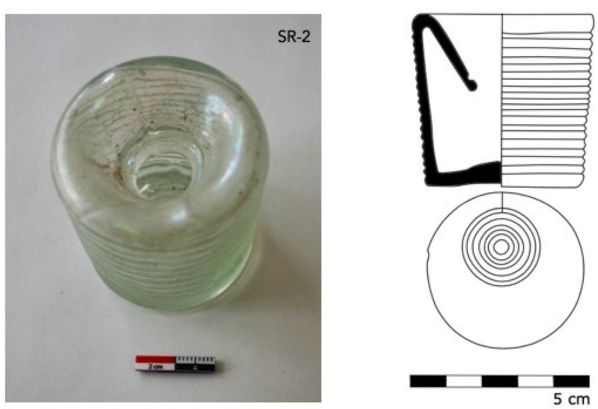


Figure 101. Inkwell recovered in Puebla (photo and drawing: Karime Castillo).

7.1.2.6. Flat Glass

This category includes glass that has no intentional cross-section curvature and was meant to be a flat, such as glass for windows or mirrors. While window glass is not the subject of this study and no flat glass from Mexico City was included,[244] some small fragments of very thin flat glass from Puebla were incorporated in the study given the limited amount of archaeological glass recovered during excavations in the city of Puebla. The flat glass fragments from Puebla are all very thin, mostly colorless but there are a few fragments with an aquamarine tint (Figure 102 left). Of the three methods to produce window glass before the twentieth century – the crown, cylinder, and plate glass methods–, the crown type tends to produce thinner glass, with the smallest thickness reported being 0.045 in (1.14 mm) (Roenke 1978:35, 44, 116), but according to Roenke (1978:6), crown glass was mostly produced in England while the rest of Europe used the cylinder method.

Figure 102. Thin flat glass fragments from the site San Juan de Dios, Puebla (photos: Karime Castillo).

7.1.2.7. Imported glass

The glass collections analyzed included several objects with attributes such as embossed texts, seals, or particular types of closures or decoration that related the artifact to production centers in Europe or later, in the US. These included tableware as well as different kinds of bottles such as wine bottles, mineral water bottles, and pharmaceutical containers.

[244] The flat glass in the collections of Mexico City corresponds to industrial window glass of variable thickness.

Venetian Glass

A fragment of a colorless (*cristallo*) goblet or wineglass decorated with *vetro a fili* recovered from the site Juárez 70 represents a Venetian import (Figure 103a). The fragment includes the bottom of the bowl of the wineglass, which had a conical shape, and a blown knop. The latticinio was applied as sets of three very fine vertical *lattimo* (white glass) strands that run parallel around the object and are embedded into the glass. The knop is delimited at the top and at the bottom by thin rings of clear glass. The stem or base of the object is missing but the surviving knop and fragment of the bowl suggest that the object could have had a shape similar to the goblet on Figure 103b.

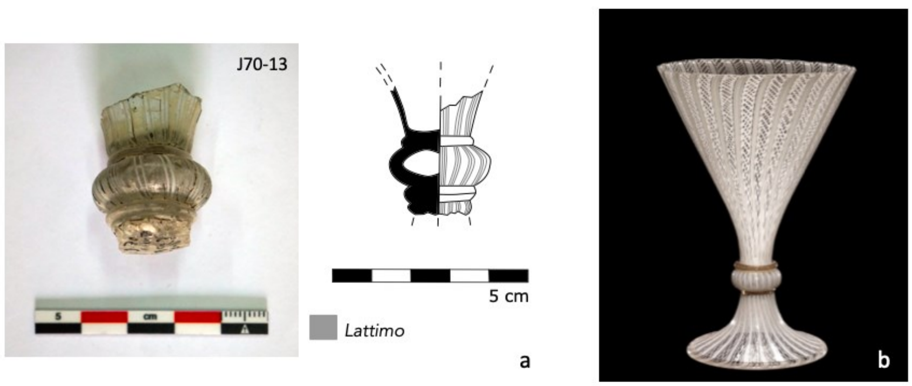


Figure 103. Venetian glass: a) fragment of a goblet or wineglass with vetro a fili found in Mexico City (photo and drawing: Karime Castillo); b) Venetian goblet with vetro a fili and vetro retorti, late 16th century (Corning Museum of Glass online catalogue).[245]

Glass *à la façon de Venise*

The material from Mexico City also includes an example of glass *à la façon de Venise* in colorless glass: a bowl with a folded rim decorated with vertical lines in white enamel imitating *latticinio* decoration (Figure 104a). This type of enameled imitation, replacing the embedded canes of *lattimo* glass, as well as the folded rim can be seen in Venetian style objects from

[245]https://www.cmog.org/artwork/goblet-313?search=collection%3Ad5d3ce5e2680a2a3ddc02475cf56a7b4&page=5

Catalonia (Figure 104). This does not mean, however, that embedded *lattimo* was not used in Catalonia. Instead, it indicates that two different techniques were used in Catalonia to imitate Venetian glass: 1) by coping the actual techniques used in Venice (Figure 104c); and 2) by imitating the decoration with enamels. It should be noted that glass *à la façon de Venise* was also produced in Castile. However, Castilian examples, which are made with embedded *lattimo* canes, tend to be later and produced at the Real Fábrica de Cristales de La Granja.

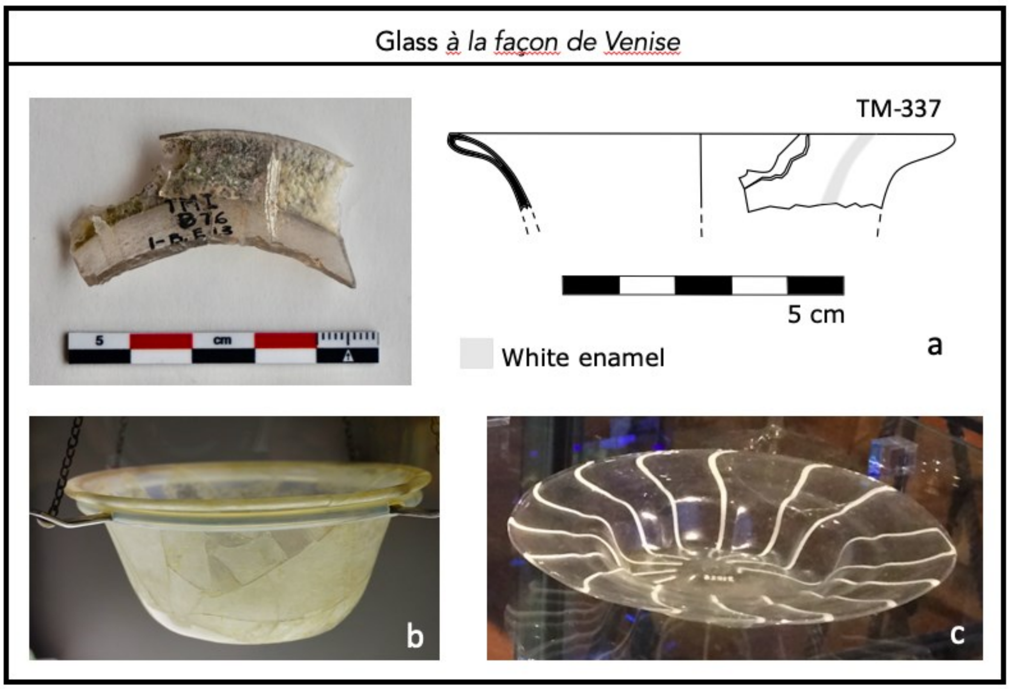


Figure 104. Glass à la façon de Venise: a) fragment of bowl with folded rim and decorated with white enamel found in Mexico City; b) bowl with folded rim, 17th-18th century, El Born CCM; c) Catalan plate with embedded lattimo canes, 17th century, Museu Cau Ferrat (photos and drawing: Karime Castillo).

Enameled blue glass

Aside from the enameled glass *à la façon de Venise*, no other objects in the collections had enamel except for the fragment of a blue phial recovered from the site Juarez 70 (Figure 105a). Blue glass decorated with white enamel was sometimes made in Catalonia in the sixteen and seventeen centuries, as shown in a phial fragment recovered at El Born in Barcelona (Figure 105b). This type of glass was probably an imitation of blue glass with *lattimo* made in Venice

(Figure 105c). As in the imitation of *cristallo* mentioned above, the decoration on both phials, from Barcelona and the Juárez 70, was made with white enamel instead of *lattimo* embedded in the glass body, although the later technique was also used in Catalonia, as shown in Figure 105d.

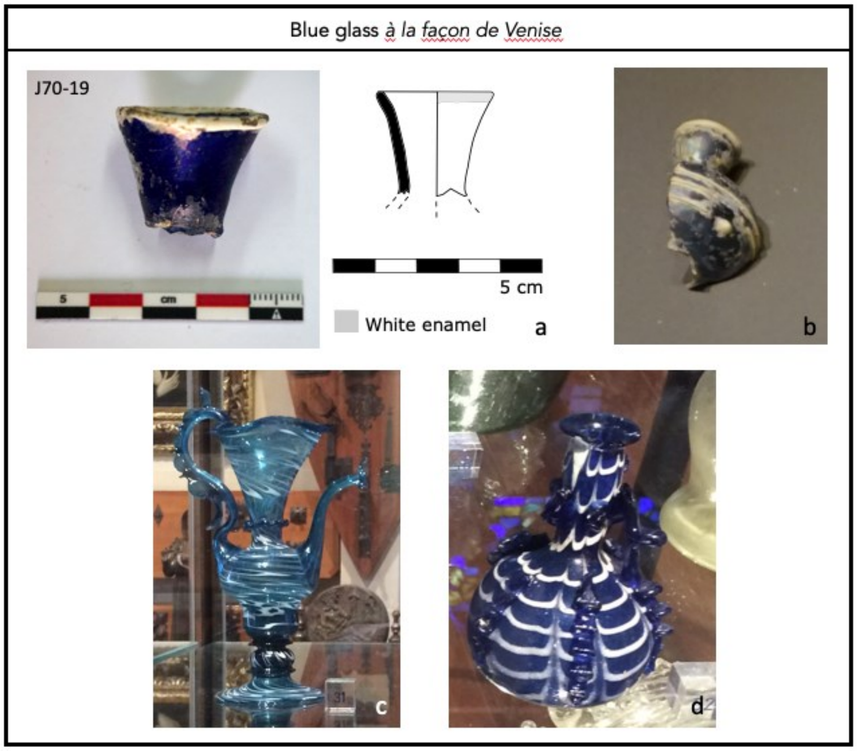


Figure 105. Enameled blue glass: a) top of a phial with a white-enameled lip fond in Mexico City; b) small phial decorated with white enamel, El Born CCM, early 18th century; c) Venetian jug with lattimo, late 17th-early 18th century, Museu Cau Ferrat; d) Catalan flagon with lattimo, 18th century, Museu Cau Ferrat (photos and drawing: Karime Castillo).

Opaque Red Glass (Hyalite glass?)

Among the material found in the site Apartado/Nicargua, there is a rim of a wide-mouth vessel with very thin walls made of dark red and black glass. Both colors seem to swirl around the object forming linear patterns (Figure 106a). This type of glass was made in German glass workshops since at least the fifteenth century (Figure 106b) and continued to be made during the seventeenth century (Drünert et al. 2018:376; Steppuhn 2009:69-70). Objects made of this material have also been found in excavations at El Born in Barcelona (Figure 106c), and the exconvent of San Jerónimo in Mexico City (Hernández Arana 1980:32). Noteworthy is the presence of fragments of glass crucibles with remains of opaque red glass (Figure 77c, 11d) and small chunks of the same material (Figure 65) in the collections recovered from the sites Bolivia 16 and Juárez 70, which could indicate remelting or local production.

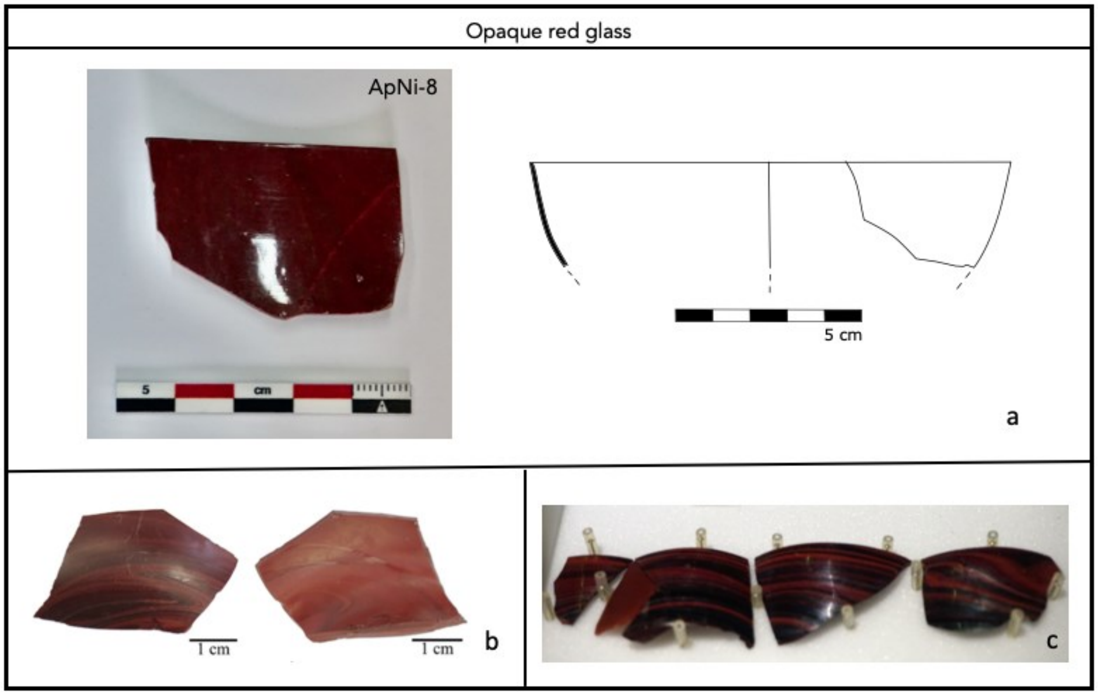


Figure 106. Opaque red glass: a) rim of a bowl from the site Apartado/Nicaragua in Mexico City (photo: Karime Castillo); b) fragments from Glashütten/Taunus Mountains, 15th century (Drünert et al. 2018:376; detail of Fig.1); c) rims of bowls recovered at El Born,17th-18th century, El Born CCM, Barcelona (photo: Karime Castillo).

## Engraved Glass

A few examples of wheel-engraved colorless glass decorated with linear and geometric designs are present in the collections of Mexico City and Puebla (Figure 107). This type of decoration is commonly found in the fine glass that was made in the eighteenth and nineteenth centuries at Real Fábrica de Cristales de la Granja, located in the vicinity of Segovia in Spain. From 1760 to 1810 fine glass from this royal factory, was shipped to New Spain. Most of the articles shipped represented out-of-fashion unsold surplus, but some in vogue items were included to showcase the variety of articles made at the royal factory (Pastor Rey de Viñas 1994:38). Engraved glass with this type of decoration remained popular even after the Mexican independence, and derived in a local wheel-engraving tradition known as *vidrio de pepita* (seed glass).

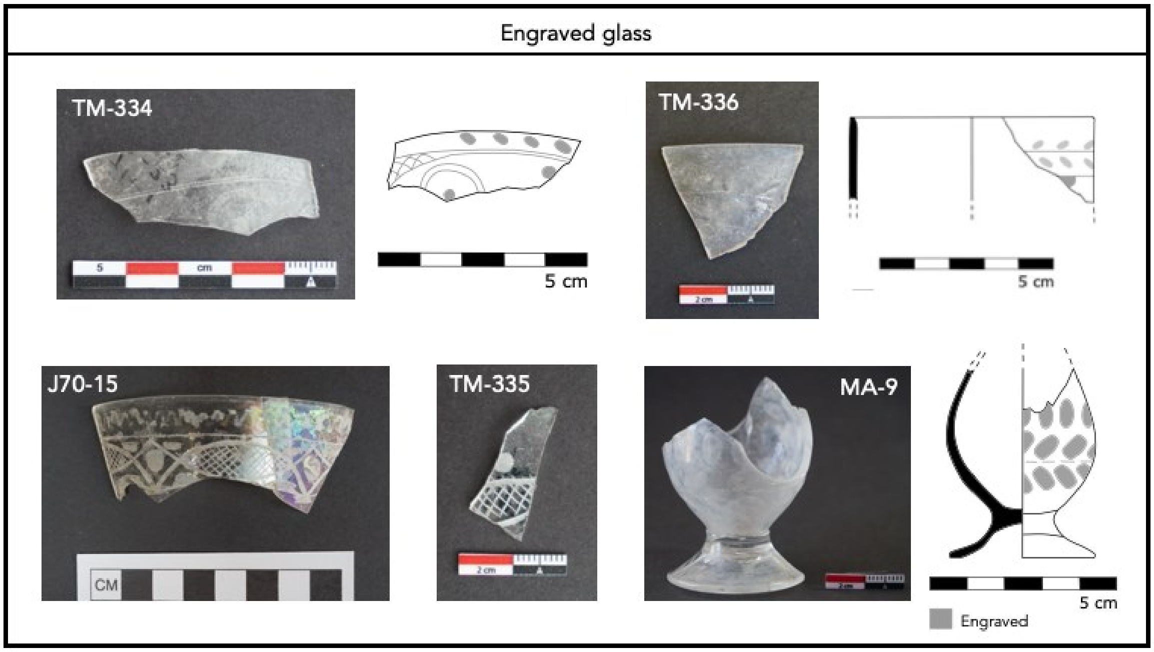

Figure 107. Engraved glass found in Mexico City and Puebla (photos and drawings: Karime Castillo).

Dark Green Wine Bottles

Among the mold-blown wine bottles recovered in Mexico City, there are some that have embossed bases with the texts: "H·Ricketts & Co :·: Glassworks Bristol" (Figure 108a) and "Manning & Marshall" (Figure 108b) . These bottles were made using three-piece molds of the Rickett's type with a base plate. Both types of bottles date to the nineteenth century. Most bottles embossed on the base with "H·Ricketts & Co, Glassworks Bristol" first appeared in England in 1821. Several variants of this base embossing exist, but when it occurs in a continuous circle – like the ones found in Mexico – they date after 1835 (Fletcher 1976:25; Jones 1983:176-177). While the bottles embossed "Manning & Marshall" could also come from England, they might have a different origin. After the Mexican Independence opportunities arose for foreign companies to invest in the new republic. In the mid-1920s, two merchants who represented an English company investing in Mexico, Robert Manning, from a British family but born in Barcelona, and the Englishman William Marshall, founded the Manning and Marshall trading house in Mexico City with a branch in Veracruz. Their business was dedicated to commerce within the new republic in commodities like tobacco and a beer company in Mexico City. Their investments later expanded into mining, and after Manning's death and Marshall's eventual return to England the company came under Ewen Mackintosh's management (Meyer 1987:57-58, 60). The embossing on these bottles suggests that they were commissioned by the Manning and Marshall trading house. In 1828 they rented space at the Hospicio de Pobres, to establish a beer factory which remained active until 1863 although its management changed hands several times throughout the years (Reyna and Krammer 2012:83).

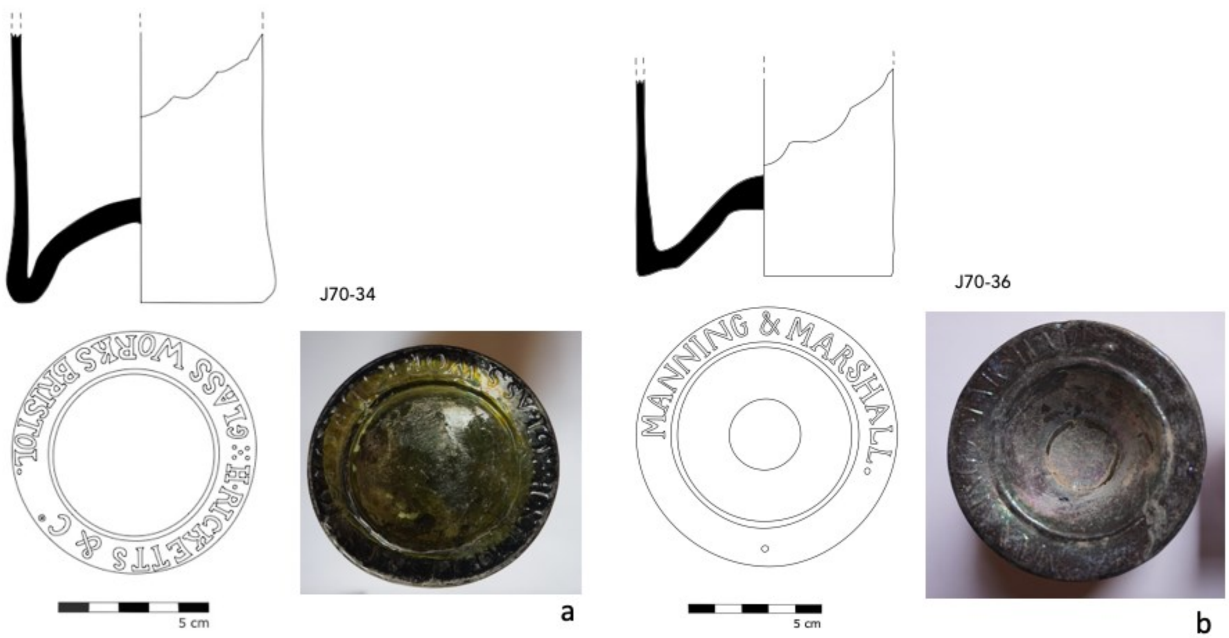


Figure 108. Base-embossed bottles: a) H. Ricketts & Co. Glassworks Bristol bottle; Manning & Marshall bottle (photos and drawings: Karime Castillo).

Wine Bottle Shoulder Seals

The practice of attaching glass seals to the shoulder of wine bottles became common in England during the seventeenth century. Seals were made by applying a small gob of glass to a hot bottle and then impress it with a stamp. Originally, seals indicated a specific tavern or upper-class person but were later used to indicate merchants, distillers, and shipping agents. The use of seals began to decline in the late nineteenth century with the advent of plate molds (Munsey 1970:59; Noël Hume 2001:61-62). Wine bottle shoulder seals dated to the nineteenth century were recovered in Mexico City from the sites Bolivia 16, Juárez 70, and Libertad 35. Most of the seals recovered correspond to Médoc wines from different vineyards in the region of Bordeaux, France, including St. Julien (Figure 109a and 109b), Pauillac (Figure 109c), B. Danglade (Figure 109d), and Chateau Leoville (Figure 109e). There is also a seal of unknown origin with the initials "R&C" (Figure 109f) which might stand for the name of a particular patron, and a seal of a Portuguese wine from the island of Madeira (Figure 109Figure 109. Additionally, there are seals from nineteenth-century bottles made in the USA bearing the text: A·Bininger & Son New York / Broad Way 141" in one case (Figure 110a), and "Tabac de J. Delpit Nouvelle Orleans" in the other (Figure 110b).

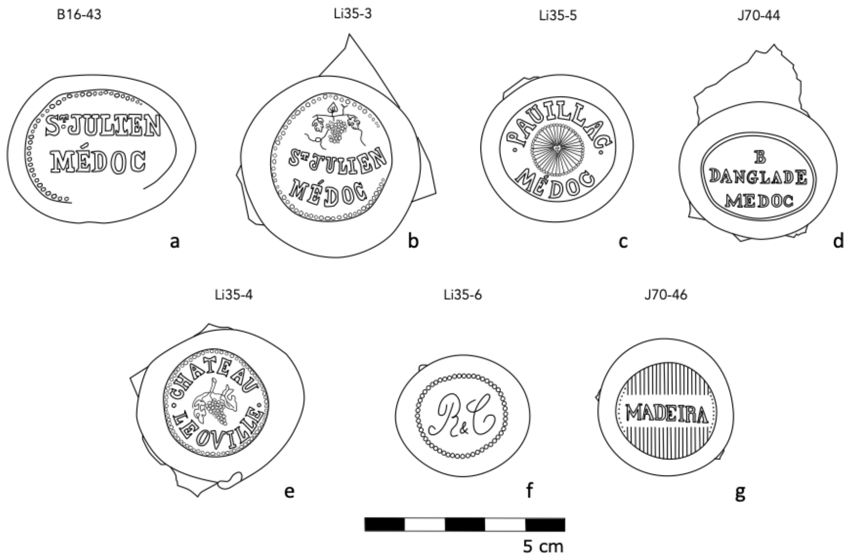


Figure 109. Wine bottle shoulder seals: a) St. Julien Médoc; b) St. Julien Médoc with grapes; c) Pauillac Médoc; d) B. Danglade Medoc; e) Chateau Leoville; f) R&C; g) Madeira (drawings: Karime Castillo).

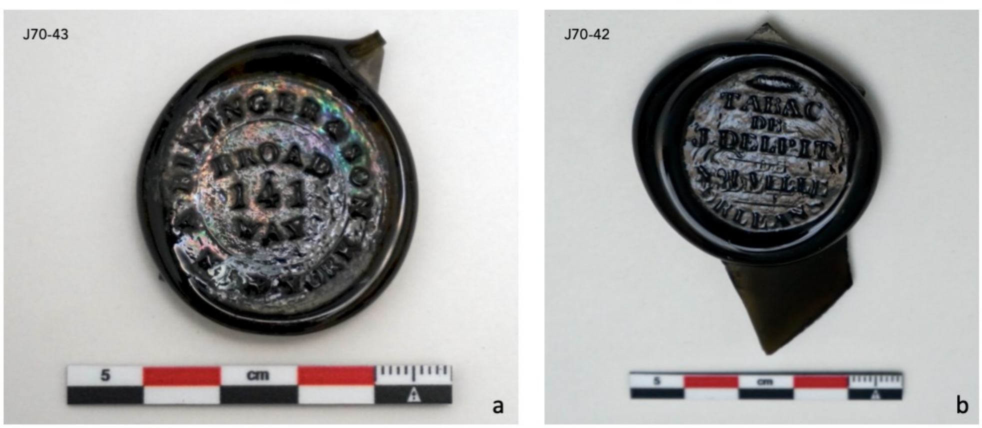


Figure 110. Wine bottle seals from the USA: a) A·Bininger & Son New York; b) Tabac de J. Delpit Nouvelle Orleans (photos: Karime Castillo).

Mineral/Soda Water

One fragment from the top of a bottle recovered in the site Los Sapos in Puebla (Figure 111) presents a distinct kind of stopper made of metal wire bent in an "8" shape with two disks at the bottom that used to hold a rubber gasket. This type of stopper, known as Hutchinson or spring stopper, was designed for bottles containing soda/mineral water. It was patented in 1879 in the United States and remained in use until the early twentieth century. The stopper could be used in different bottles, working better on those with a short neck, and could be reused as long as the rubber seal was in good shape (Jones and Sullivan 1989:162). The bottle found in Puebla associated with this kind of stopper is made of thick aquamarine glass, has a tooled blob finish, a short neck, and a narrow sloping shoulder. The color, shape, and thickness,[246] of the artifact are consistent with the mainstream characteristics of the soda/mineral water bottles of the time; usually they were also embossed with the company or product name (Lindsey 2020), but there are no remains of the body of the artifact from Los Sapos, Puebla.

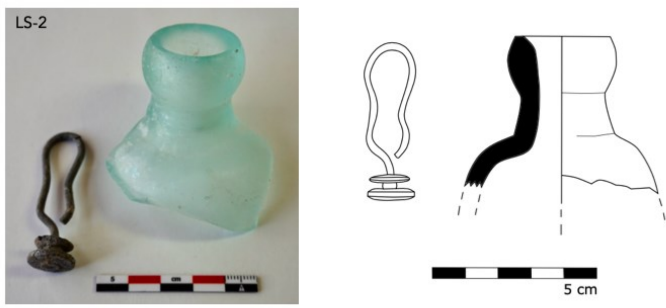


Figure 111. Soda bottle with blob finish and Hutchinson stopper (photo and drawing: Karime Castillo).

Patent and proprietary medicine phials and bottles

Patent medicines originated in England in the mid-eighteenth century. The makers of cures that achieved significant reputation began to mark their bottles and impress their names on wax seals, a practice that eventually led to the use of embossed bottles with the name of the medicine or maker (Fletcher 1976:33). For a patent to be conferred, the ingredients of the medicine had to be indicated and the formula was only protected until the patent expired. To protect their formulas, many makers would register the brand name instead; these are known as proprietary medicines. While initially these medicines would be sent from Europe to the Americas, patent and proprietary medicines began to be made in the USA after the

[246] The thick glass allowed the bottle to withstand the carbonation pressure (Lindsey 2020).

Revolutionary War and by 1810 there were close to a hundred of them (Munsey 1970:65-66). The collections from Puebla and Mexico City included examples of embossed medicine bottles from the USA.

Sarsaparrilla Medicine Bottles

A fragment of a side panel of a Bristol's Sarsaparilla medicine bottle (Figure 112a) was recovered from the site Libertad 35 in Mexico City. This product was introduced in the early 1830s and was manufactured by Cyrenius C. Bristol in Buffalo, NY. Different versions of sarsaparilla bottles exist, but most of them are aquamarine rectangular-section bottles. Some bottles present the embossed text "Extract of Sarsaparilla" on the frontal panel, and the texts "Bristol's" and "Buffalo" on each of the side panels, while others have the text "Genuine Sarsaparrilla" on the front, and the texts "Bristol's" and "New York" on each side (Figure 112b) (Fike 2006:214). It is not possible to determine which of the two versions of the bottle corresponds to the fragment from Libertad 35, given that the embossed text "Bristol's" is present in both versions. The fragment from Libertad 35 shows the text "Bristol" but it probably originally read "Bristol's" given that its shape, color, and embossing is consistent with those of nineteenth century sarsaparilla bottles.


Figure 112. Bristol's Sarsaparrilla bottle: a) fragment recovered in Mexico City (photo and drawing: Karime Castillo); b) complete example showing the front and lateral panels (Wicker 2019: https://www.bottlepickers.com/bottle_articles156.htm).

Cough Patent Medicine Bottles

In the material from the site Museo Amparo, Puebla, there are fragments of an aquamarine rectangular-section bottle embossed with the text “DR. BELL'S PINE - TAR - HONEY FOR COUGHS AND COLDS” on the front panel, while on the side it bears the text “DR. BELL’S.” The base embossing shows an elongated diamond with a letter "I" inside representing the logo of the Illinois Glass Co (Figure 113). This medicine was made by the Sutherland Medicine Company and appears in newspaper advertisements of the late-nineteenth century (Weekly Kentucky New Era 1896). The embossed bottles were manufactured by the Illinois Glass Co until the late 1920s (Fike 2006:88). Interestingly, a version in Spanish of this type of bottle, embossed: “MIEL Y ALQUITRAN DE PINO DEL DR. BELL” was produced later in Mexico by Vidriera Monterrey, an example of which was recovered in excavations at the ex-convent of San Jerónimo in Mexico City (Hernández Arana 1980:63).

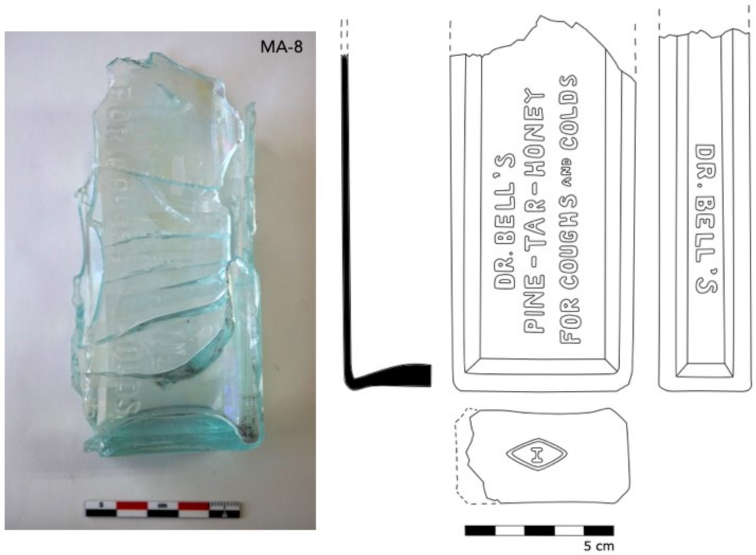


Figure 113. Embossed medicine bottle of Br. Bell's Pine - Tar - Honey for Coughs and Colds (photo and drawing: Karime Castillo).

## 7.2. Archaeological glass from Spain

While there are multiple art history books devoted to Spanish glass in general (e.g., Frothingham 1963; González Peña 1984; Pérez Bueno 1942), as well as some regional studies and scientific studies of glass from the Roman and Medieval periods (Carmona et al. 2005; de Juan Ares and Schibille 2017a, 2017b; Gimeno and Pugès 2002; Gimeno et al. 2008; Heras 2008), few publications focus on archaeological glass from the Early Modern period and later. There is also a limited number of studies that include the scientific analysis of post-medieval glass collections (Capellà Galmés and Albero Santacreu 2015; Mazadiego Martínez et al. 2006; Rosillo Martínez et al. 2014, 2015; Rosillo Martínez et al. 2017) and stained glass windows (Carmona et al. 2006; La Iglesia et al. 1994; Palomar et al. 2010; Pradell et al. 2016). In order to adequately understand colonial Mexican glass, it is necessary to learn more about Spanish glass traditions given that the first glassmakers were of Spanish origin. The numerous studies on the regional aesthetic development of Spanish glass are invaluable resources in the identification of glass objects, however, more studies are needed that focus on the technology in terms of raw material selection and use. In order to fill in some of the gaps in technological information, a small collection of archaeological glass from Catalonia, one of the major glass production centers in early modern Spain, was included in this study. This section presents a typology of Catalan glass.

### 7.2.1. The Archaeological Sites

Two Catalan archaeological glass collections, one from Barcelona and one from Sant Bartomeu del Grau in the province of Vic, Osuna, were analyzed in this study. The location of the archaeological sites can be seen in Figure 114. Brief descriptions of the sites, their stratigraphy, and an overview of the glass recovered are available in Table *5*Table *4*. This is followed by a proposed typology for Catalan glass that integrates the material from both sites.


Figure 114. Location of the archaeological sites in Catalonia.

Table 5. Description of the sites in Catalonia.

| Catalonia | | | | | |
|---|---|---|---|---|---|
| **Site** | **Location** | **Excavation** | **Archaeological Context** | **Glass Artifacts** | **Notes** |
| Barcelona-Carrer Antic de Sant Joan<br><br>Site code: 002/17 | District: *Ciutat Vella* (old city)<br><br>Between streets Carrer Antic de Sant Joan (No. 1-5 and 2-12), Carrer del Rec (No. 36), and Passeig del Born. | Excavated as part of a rescue archaeology project performed by Global Geomática, SL (Alegría Tejedor 2019; Servei d'Arqueologia de Barcelona 2018).<br><br>Excavation units: extensive unit over the whole road. | Stratigraphy: modern-day pavement, demolition fills, remains of early modern structures and a road (carrer Joc de la Pilota), remains of a medieval road, and a sandy layer. The contexts were disrupted by two modern-day water collectors.<br><br>Features:<br>• At the time of excavation: modern-day pavement.<br>• Modern period: street pavements, drains, a laundry tub, a water well, and the basement of a building fitted with stone steps and a chimney.<br>• Medieval period: remains of a house and a road, and some burials.<br>• Antiquity: part of a Roman necropolis ($2^{nd}$-$4^{th}$ century CE). | Total artifacts:<br><br>Material analyzed:<br>· bottles<br>· thin flat glass<br>· tableware (wineglasses and other vessels) | The glass artifacts date to the late-$17^{th}$ and early-$18^{th}$ centuries. |
| Old church of Sant Bartomeu del Grau | Province of Vic (Osuna), to the east of the town Sant Bartomeu del Grau, on Camí del Roc Llarg 08503, on the east side of the road that leads to the local cemetery. | Excavated by the Centre d'Investigacions Arqueològiques d'Osona as part of a restoration and archaeology project (Casas Blasi 2005).<br><br>Excavation units: Trenches and an extensive unit to recover the original plan of the church. | Stratigraphy: vegetation, a level of construction rubble (blocks of calcareous rock, ceramic roof tiles, lime mortar) from the collapse of the church, a stone slab floor, a levelling fill, and bedrock.<br><br>The Romanic church of Sant Bartomeu del Grau was built in the $10^{th}$ century. It was surrounded by a settlement that was ravaged by the bubonic plague of 1348. It was abandoned in 1780 when a new church was built in the town of Sant Bartomeu del Grau. The site was never reoccupied and the church eventually collapsed, except for a wall that still stands today (Casas Blasi 2005:7-9). In 2017 it was opened to the public as a memory space for the town (Pedragosa Batllori and García Fernández 2017).<br><br>Features:<br>• At the time of excavation: ruins of the church covered in vegetation; part of the land was used for agriculture.<br>• Modern period: funerary structures, foundations of a new sacristy and a side chapel.<br>• Medieval period: original church foundations and remains of walls, floors, and stair steps.<br>• Antiquity: no evidence reported (Casas Blasi 2005:12-30) | Total artifacts:<br><br>Material analyzed:<br>· bottles<br>· phials<br>· thin flat glass | The glass artifacts date to the $17^{th}$ and $18^{th}$ centuries. |

7.2.2. Typology of Catalan Glass

Two Spanish glass collections were included in this study that included 47 artifacts in total, 25 from Barcelona and 22 from Sant Bartomeu del Grau. While small in number, the collections include examples of some characteristic Spanish forms such as *porrón* (wine pitcher), and *aceitera* (oilcan), and their forms and adornments reflect the Catalan tradition of glassworking. The material from both sites is presented below.

7.2.2.1. Free-Blown Glass

All of the hollowware examined in this study is free-blown except for a single mold-blown fragment. The material includes bottles, phials, wide-mouth vessels some of which have folded rims, stemware, and a few objects in typical Catalan style including spouted vessels and long neck vessels. Some of the objects were ornamented with applied trails of stretched glass and there are two small fragments that present white enamel.

*Ampolles* (bottles)

As part of the material from Sant Bartomeu del Grau there is part of a base of an *ampolla* (bottle) with a small kick-up (Figure 115). It probably had a pontil mark but the glass is too deteriorated to be certain. It should be noted that kick-up bases are not exclusive of bottles and also appear in *porrons* (wine pitchers) and *gerras* (jars).

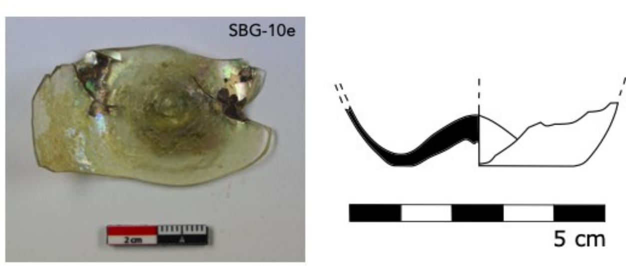


Figure 115. Base of an *ampolla* (bottle) with a kick-up (photos and drawing: Karime Castillo).

Hollowware with applied decoration

Both collections of Catalan glass have fragments of vessels with applied decoration. This type of decoration can be commonly found on Catalan glass and it can be simple or consist of very intricate designs. One of the artifacts (Figure 116a) has parallel strands of glass that resemble those on the bottom of a seventeenth century *bernegal* (drinking cup with a carinated body) from El Born, Barcelona (Figure 116b).

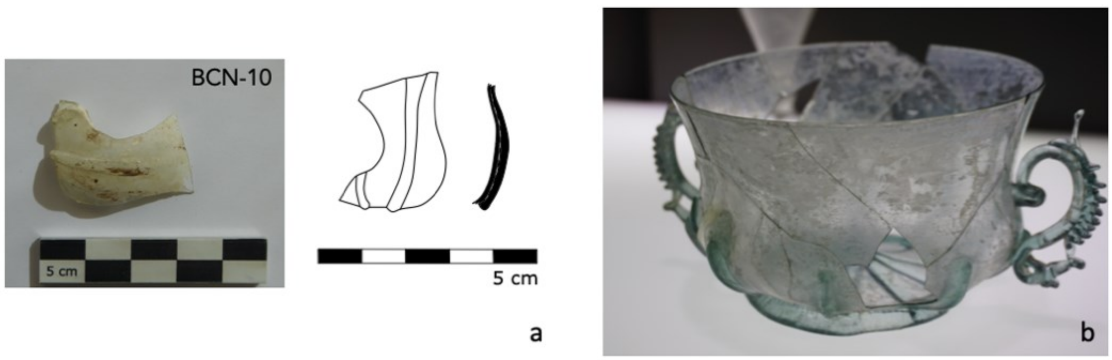


Figure 116. Vessels with applied decoration: a) fragment of vessel with applied strands of glass; b) *bernegal,* 17th century, Catalonia, El Born CCM, Barcelona (photos and drawing: Karime Castillo).

Undulating glass ribbons are another type of applied decoration common in Catalan vessels, an example of which can be seen in the candleholders on display at the Museu del Vidre de Vimbodí (Figure 117b). The base of a vessel from Barcelona displays this type of ribbon around the base (Figure 117a).

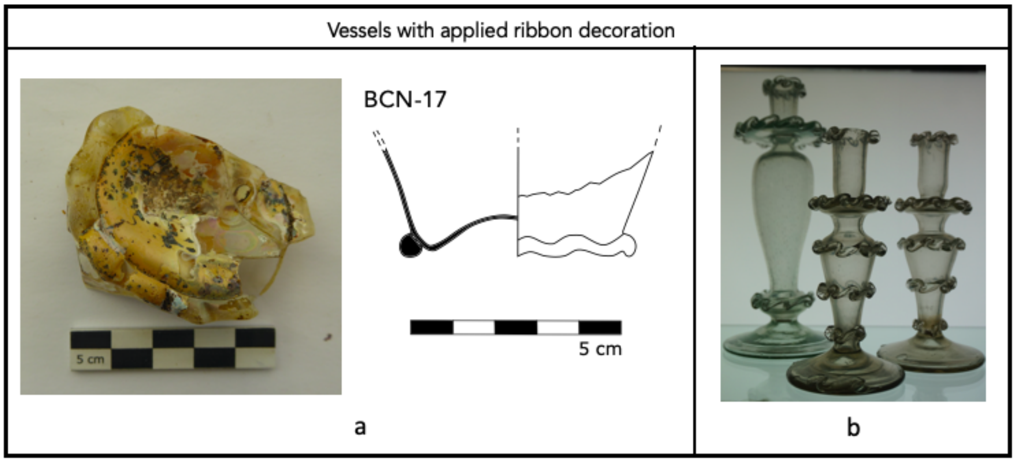


Figure 117. Vessels with applied ribbon decoration: a) fragment of the base of a vessel with applied ribbon decoration from Barcelona (photo: Trinitat Pradell, drawing: Karime Castillo); b) candleholders decorated with applied ribbons, Museu del Vidre de Vimbodí (photo: Karime Castillo).

Hollowware with folded rims, bases, or adornments

The collection from Barcelona includes examples of a thin colorless glass vessels with a folded rim (Figure 118a and b), although one of them (*Figure 118*a) might be part of a folded base. Many Catalan glass objects have folded features, for example, the folded base of the *fiala* (vial) in *Figure 118*c and the folded rim of the *llàntia* (lamp) on Figure 118d.

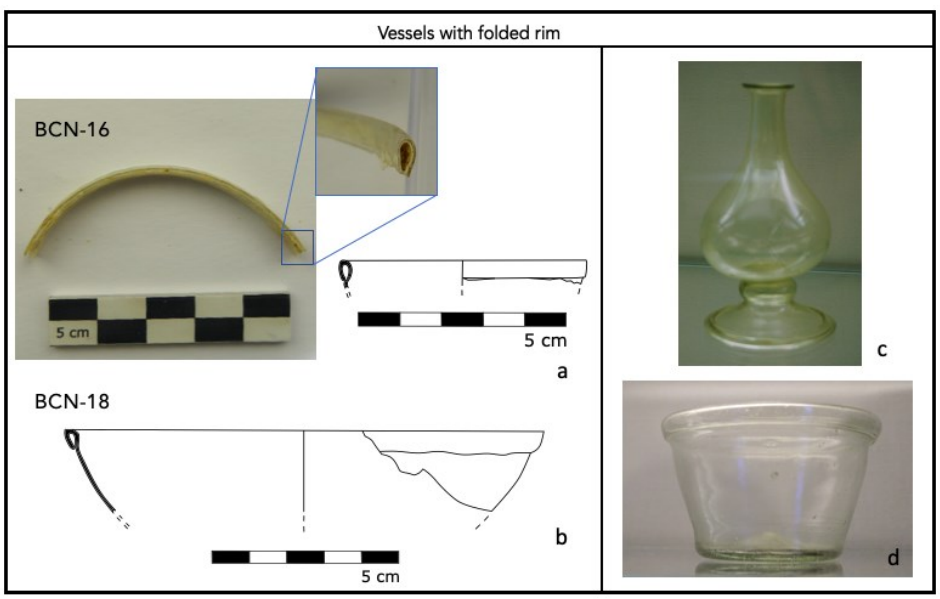


Figure 118. Vessels with folded rim or base: a) fragment of a folded rim/base from Barcelona (photos: Trinitat Pradell, drawing: Karime Castillo); b) fragment of folded rim (drawing: Karime Castillo); c) *fiala*

or vial, 18th century, Museu Episcopal de Vic (photo: Karime Castillo); d) *llàntia* or lamp with folded rim, 17th century, Museu Episcopal de Vic (photo: Karime Castillo).

Folds can also be found in other parts of a vessel. Two artifacts show a fold and breakages that indicate that the walls of the vessel continued, so the fold was somewhere in the body rather than on a rim or a base. One of these artifacts, recovered in Barcelona, is made of thin colorless glass (Figure 119a), while the other one, found in Sant Bartomeu del Grau is made of blue glass (Figure 119b). Folded decoration of this type can be seen in the *llàntia* or lamp on Figure 119c.

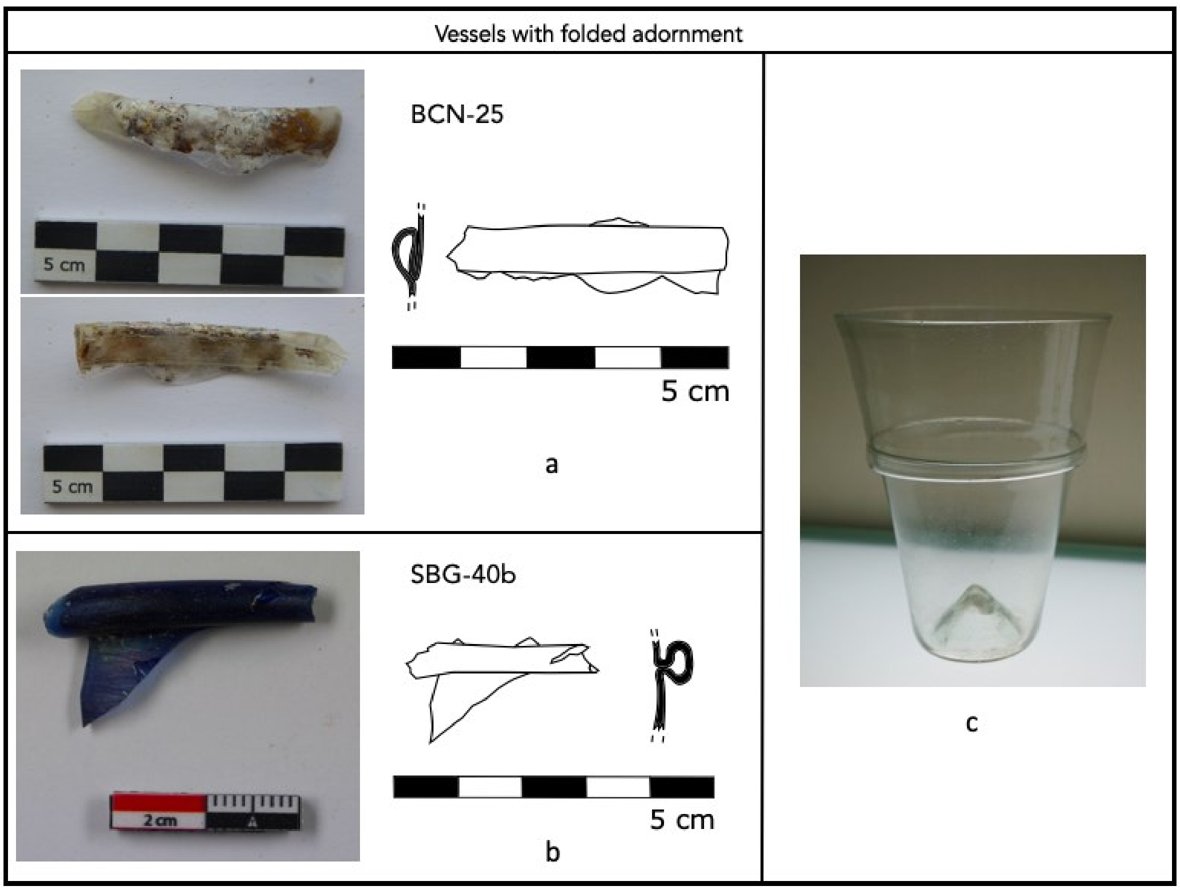


Figure 119. Vessels with folded adornments: a) fragment of colorless vessel with fold from Barcelona (photos: Trinitat Pradell, drawing: Karime Castillo); b) fragment of blue vessel with fold from Sant Bartomeu del Grau; c) *llàntia* or lamp with central decorative fold, 18th century, Museu Episcopal de Vic (photos and drawings: Karime Castillo).

Long neck vessel

The collection of Sant Bartomeu del Grau includes the top of a green glass vessel with a very long neck, an everted rim, and a rounded lip (Figure 120a). The fragment could have belonged to different objects such as *ampolles* (bottles) or *porrons* (Figure 120b and 17c respectively), among others.

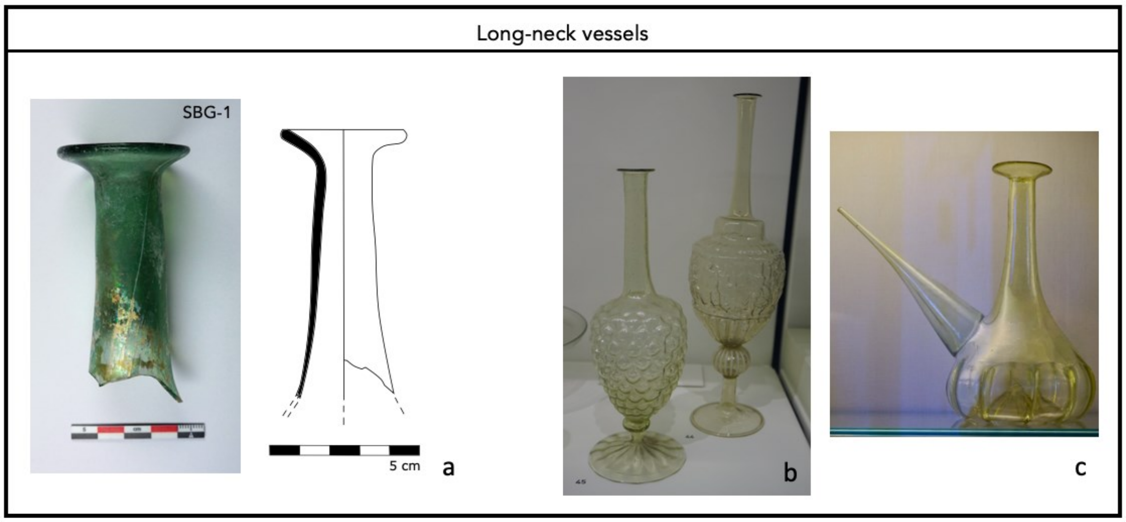


Figure 120. Catalan long neck vessels: a) fragment of a long-neck vessel from Sant Bartomeu del Grau; b) *ampolles* (bottles), 17th century, Museu del Disseny, Barcelona; c) *porró*, 18th century, Museu Episopal de Vic (photos and drawing: Karime Castillo).

Spouted vessels

*Porró* (wine pitcher)

The collection from Sant Bartomeu del Grau contains a fragment of a possible spout of aquamarine glass (Figure 121a). Considering its narrow diameter, it is unlikely that it represents another type of object such as a phial. However, it could have been part of the spout of a *porró* (wine pitcher). The piece does not show any bends so it was probably straight like the examples on Figure 121b and 121c.

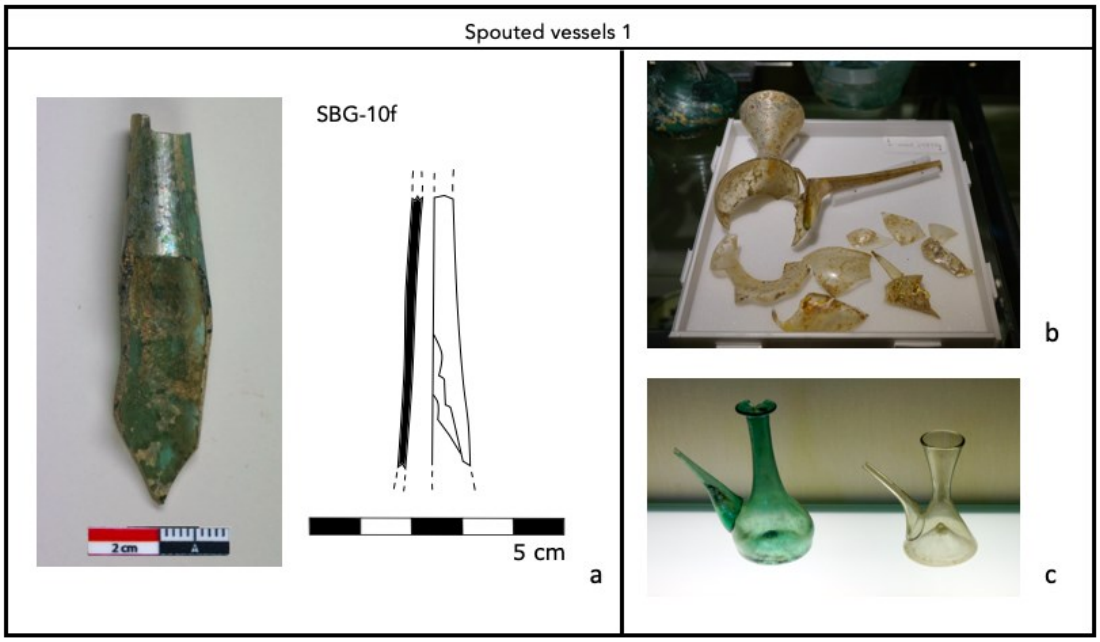


Figure 121. Catalan spouted vessels: a) fragment of a straight and narrow spout from Sant Bartomeu del Grau; b) remains of a *porró*, 17th-18th century, El Born CCM, Barcelona; c) *porrons*, 19th century, Museu Episcopal de Vic (photos and drawing: Karime Castillo).

*Càntir or Setrill*

The glass recovered in Barcelona includes a blown spout in blue glass that could have belonged to a *càntir* ( jug) or to a *setrill* (oilcan). The object is semi-globular at the bottom, the area that would have been attached to the body of the *càntir/setrill*, and gradually narrows towards the top to form a narrow tube that bends forward (Figure 122a). An example of both a *càntir* and a *setrill* can be seen on Figure 122b (right and left respectively).

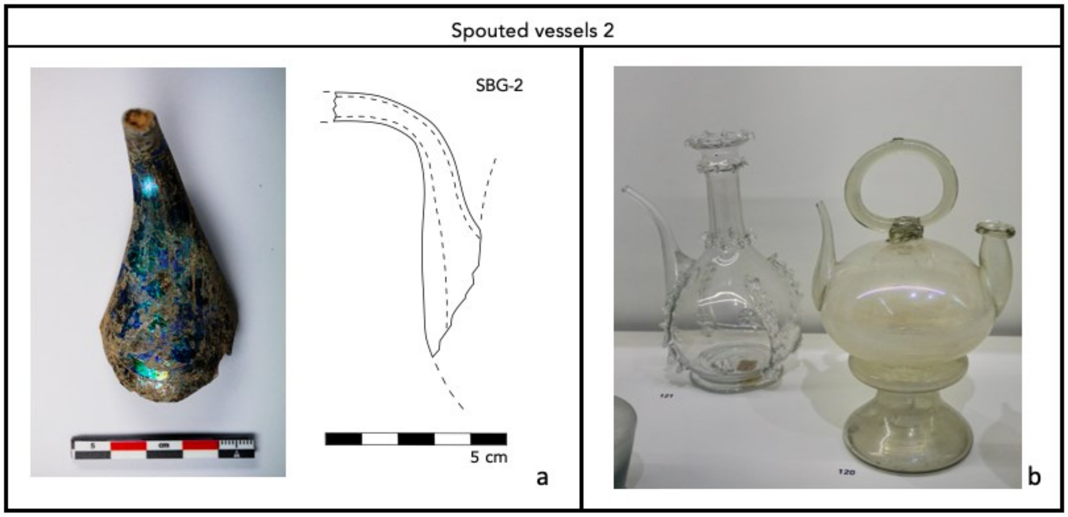


Figure 122. Catalan spouted vessels: a) spout of a *càntir/setrill*; b) examples of a *setrill* (left) and *càntir* (right), 18th-19th century, Museu del Disseny, Barcelona (photos and drawing: Karime Castillo).

Stemware

The Catalan collection includes a few stemware artifacts including fragments of feet of wineglasses and of a blown knop or bowl of a Venetian style wineglass (discussed below). Both feet are of a plain conical shape; one of them shows subtle radial grooves around its top (Figure 123a), while the other one is plain (Figure 123b).

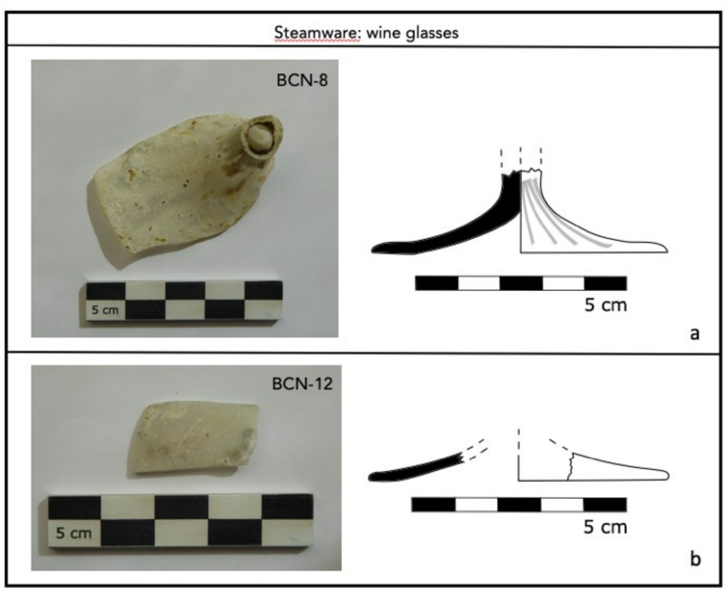


Figure 123. Stemware: a) foot of a wineglass with radial grooved decoration; foot of a wineglass (photos: Trinitat Pradell; drawings: Karime Castillo).

Pedestal bases

Catalan glassmakers made a variety of pedestal vessels such as wine glasses, candlesticks, serving plates, and many other items. In the collections examined there is a fragment of the base of one such vessels (Figure 124). Considering that the lip is slightly raised, it is unlikely that this artifact represents the rim of a vessel and more likely represents a pedestal base.

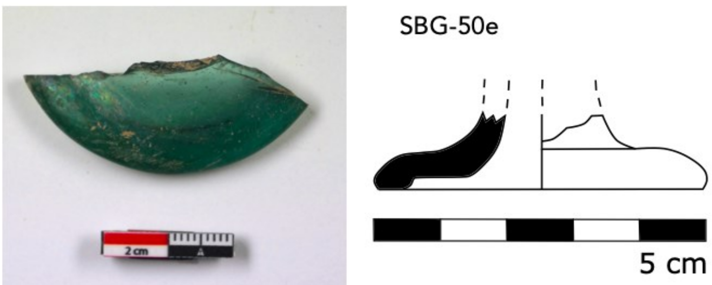


Figure 124. Fragment of a pedestal base from Sant Bartomeu del Grau (photo and drawing: Karime Castillo).

Glass *à la façon de Venise*

Since the sixteenth century, glass in Venetian style was made in Catalonia. Local artisans learned the techniques from Muranese glassmakers who moved to the Iberian Peninsula. However, glass *à la façon the Venise* made in Catalonia was not a mere imitation, instead, it was an adaptation based on the local glassmaking tradition, which included thin colorless glass vessels and sophisticated use of enamels (Doménech 2004:85, 87, 91). As mentioned above, the technique to embed *lattimo* canes into the vessel walls was known and used in Catalonia, but in many cases the lattimo would not be fully incorporated into the walls, creating texture on the surface (Doménech 2004:100-101), or was replaced by white enamel. Two small fragments of enameled glass, which may have belonged to the same object, were recovered from the site in Barcelona (Figure 125a). Both objects are decorated with vertical parallel lines of white enamel imitating *latticinio*. Both objects have a globular shape and could have been part of a blown stem knop or the bottom of the bowl of a wineglass like the one shown on Figure 125b.

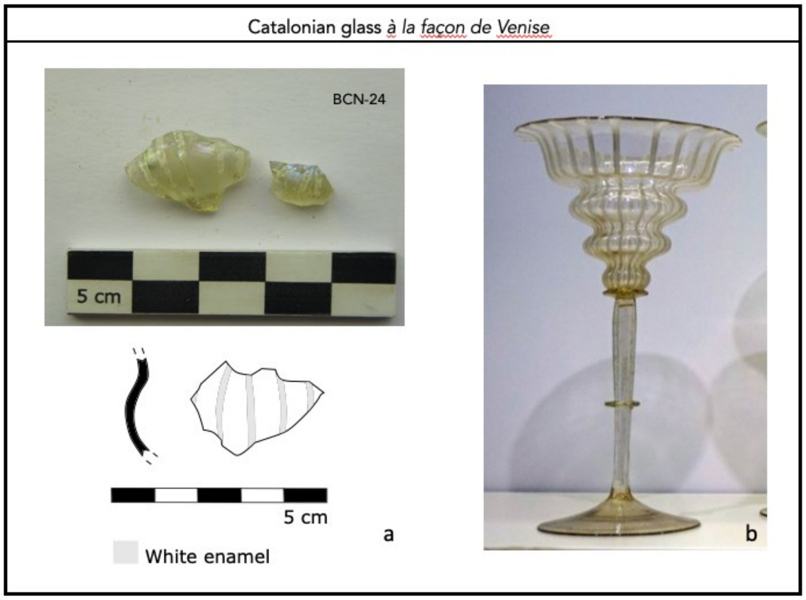


Figure 125. Catalan glass à la façon de Venise: a) fragment of a knop/bottom of the bowl of a wine glass with white enamel imitating latticinio (photo: Trinitat Pradell; drawing: Karime Castillo); b) wine glass decorated with white enamel imitating latticinio, 17th century, Museu del Disseny, Barcelona (photo: Karime Castillo).

Ribbed vessels

One fragment recovered in Sant Bartomeu del Grau has a ribbed surface indicating that it was blown into a texturizing dip-mold (Figure 126a). Objects with this kind of decorative texture are common, an example can be seen on the fragments of long neck bottes from El Born depicted in Figure 126b.

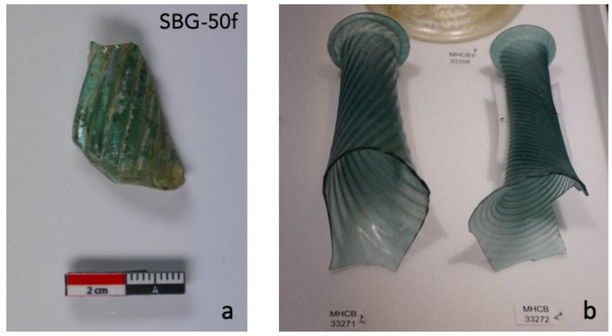


Figure 126. Ribbed vessels: a) fragment of a vessel from Sant Bartomeu del Grau; b) Top of long neck ribbed bottles, 17th-18th century, El Born CCM (photos: Karime Castillo).

7.2.2.2. Stretched Glass

The Catalan collection includes three fragments of stretched glass artifacts. Two of them are colorless and were found at the site Sant Bartomeu del Grau. One of them represents part of a handle or semi-circular adornment of colorless glass that shows a fold on the glass on one of its ends. This could have been the point where the handle/adornment was attached to the object. The handle/adornment seems to have been purposely flattened with a marking tool that left soft parallel diagonal lines on its surface (Figure 127a). The second colorless artifact appears to be part of an adornment (Figure 127b), although it could also be part of a handle (see detail on Figure 127c). The third artifact is made of aquamarine glass and was found at the site Carrer de Sant Joan in Barcelona. It represents half of a loop, thin and circular in section, which could have been part of a ring or an adornment (Figure 128).

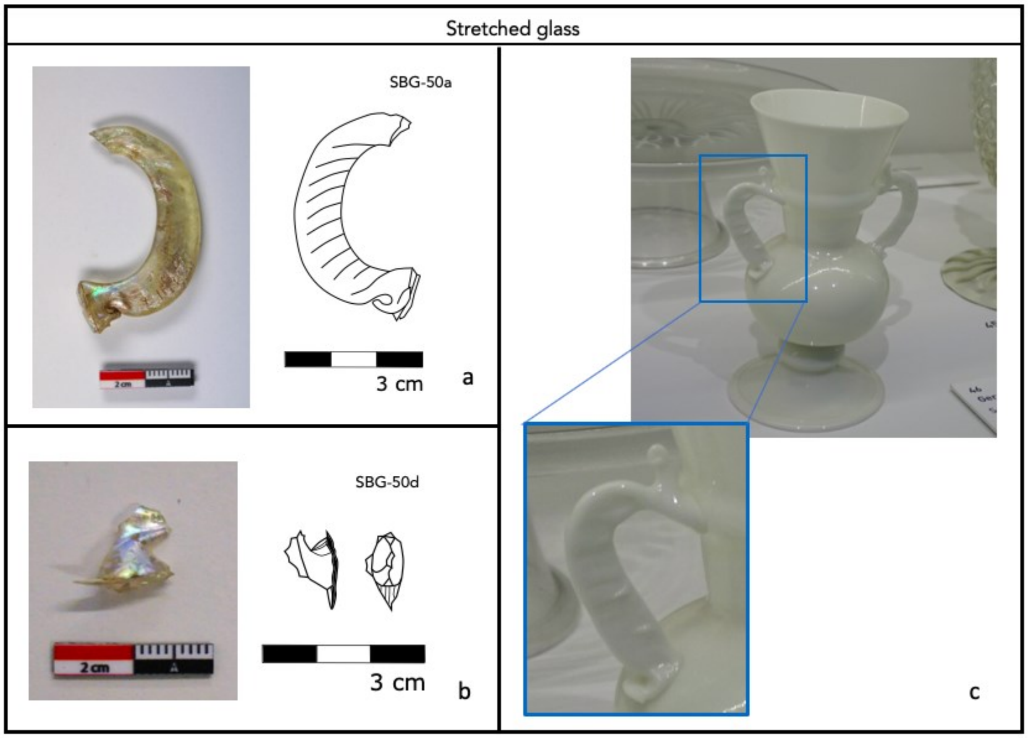


Figure 127. Stretched glass: a) handle/adornment; b) handle/adornment fragment; c) handle of a gerra or jar, 18th century, Museu del Disseny, Barcelona (photos and drawings: Karime Castillo).

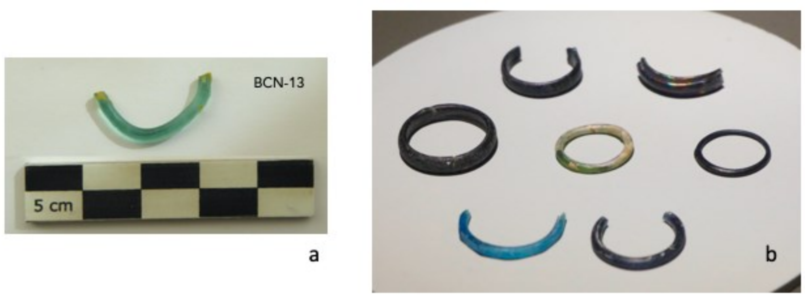


Figure 128. Glass rings: a) fragment of a glass ring/adornment from the site Carrer de Sant Joan (photo: Trinitat Pradell); b) examples of glass rings from El Born, late 17th- 18th century, El Born CCM, Barcelona (photo: Karime Castillo).

# 8. MAKING GLASS IN SPAIN AND COLONIAL MEXICO

Glass manufacture admits slight variations in the nature of its raw materials. During the production of glass, the raw materials are totally transformed and their physical characteristics lost. Through reverse engineering and using the bulk chemical data as discriminating factor, the raw materials can be identified. To shed new light into how glass technology was adapted in Mexico during the colonial period, the locally sourced raw materials for glassmaking need to be identified.

In this chapter the main raw materials of soda-lime-silica glass are discussed with focus on two potential fluxing agents: *barrilla* (a sodium plant ash) and *tequesquite* (an evaporite). The techniques employed for the characterization of the raw materials were SEM-EDS, fiber optic reflectance spectroscopy (FORS) and X-ray diffraction (XRD). Results from the analyses were used as indicator of the contribution of these materials to the composition of a given glass batch and for comparanda with the composition of the Mexican glass collections.

## 8.1. Raw Materials

The selection of raw materials is of primary importance in glass production. The type of raw materials selected for glassmaking and the proportions of each material added to the batch have a critical effect on the fusion properties, working qualities, and performance characteristics of the resulting glass. As mentioned earlier, the basic raw materials used to make glass include: a network former, a network modifier, and a network stabilizer (Henderson 2013:22). Since different ingredients can be used for each of the basic components, the identification of the raw materials used can help to determine the type of glass represented by a sample. Moreover, the raw materials selected can infer technological traditions. For instance, most Roman glass was made using natron as a flux (Shortland et al. 2011), while in Northwest Europe, bracken plant ashes were used in the making of medieval and post-medieval glass (Smedley and Jackson 2002a). The following sections will describe each of the three basic components with an emphasis on those used in colonial Mexico.

8.1.1. Network former: Silica

The basic building block or network former[247] of most glasses is silica ($SiO_2$).[248] In most soda-lime-silica glasses, the most common type, silica represents *ca*. 65-70% of the composition. Silica's melting point ranges between 1710 and 1730ºC. Reaching this high temperature was not possible with the technology available in Antiquity or during the Early Modern period, but it was possible to reduce the melting point of silica by adding an alkaline component, known as the flux, to the batch (Henderson 2013:56). For glassmaking, common sources of silica include quartz pebbles, sandstone, and sand deposits in rivers and coasts, as well as inland geological deposits; chert, was used as a silica source for the making of Venetian glass in the Early Modern period (Henderson 2013:56-57). Quartz pebbles, chert, flint, and sandstone need to be crushed before they can be used to make glass; to avoid this operation, glassmakers have usually preferred sand (Foy 2001:30).

Sand is mostly a result of erosion or weathering[249] and its purity and composition depends on three main factors: the type of rock or rocks from which it is derived, the distance

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[247] The network former can also be called vitrifier.
[248] Silica has three main crystalline structures with the same chemical formula (polymorphs): quartz, cristobalite, and tridymite. By far, the most abundant of these is quartz, which forms about 12% of the earth's crust, while the other two forms can be found in certain volcanic rocks. Silica is also present in non-crystalline and microcrystalline siliceous materials like opal, flint, and chert (Henderson 2013: 56).
[249] Sand can also be formed by other mechanisms including explosive volcanism, crushing, pelletization, and precipitation from solution (Pettijohn et al 2012: 252).

that the material traveled before deposition, and the depositional environment (Henderson 2013:57; Pettijohn et al. 2012:255). Sands that derive from the weathering of crystalline rocks have a tendency towards higher levels of feldspar and heavy minerals than those that result from the weathering of arenaceous sedimentary strata. Moreover, the size, shape, and sorting of the grains of sand will vary depending on whether the sands are aeolian, fluvio-glacial or deposited in current-swept waters. This is important because the grain size of sands affects the melting behavior of the glass made from them (Henderson 2013:57), for instance, it can affect the homogeneity and seediness[250] of the glass as well as the time it takes to refine it (Cable 1958:30T-31T).

Sands have variable quantities of impurities. Costal sands often have shell fragments made mainly of calcium carbonate ($CaCO_3$) matrix, which can be introduced to the glass melt with the sand, though $CaCO_3$ could also derive from other mineralogical impurities in the sand such as mica or calcite or added deliberately. Sand can contain a wide range of minor and trace elements associated with the accessory minerals that get mixed with the quartz sand through geological processes (Degryse and Shortland 2020:121). Common inclusions in sands are clay and feldspars, which introduce alumina ($Al_2O_3$) and iron (Fe)-rich compounds into the batch. Feldspars tend to have high alumina levels and can be potassium (K)- or sodium (Na)-rich. Sodium-rich feldspars, such as plagioclase, can also contain aluminum, barium (Ba), and calcium (Ca). While alumina levels in glass can be derived from feldspars, this oxide can also be introduced through plant ashes or from the walls of the crucibles where the glass was made. Low alumina levels in glass indicate that a pure source of silica was used as the raw material (Henderson 1985:271; 2013:59-60; Moretti and Hreglich 2013:28-29).

[250] The amount, size, and distribution of air bubbles in the glass (Cable 1958: 20).

Many other mineral impurities can occur in sands like zircon ($ZrSiO_4$), ilmenite ($FeTiO_3$), chromite ($FeCr_2O_4$), and titanite ($CaTiSiO_5$), which introduce iron (Fe), chromium (Cr), titanium (Ti) and zirconium (Zr) into the glass. In addition to $CaCO_3$, shell fragments in costal sand can also introduce strontium (Sr). If inland sands were used, the levels of Sr would be expected to be lower because these sands would be associated with limestones and in some cases, may present higher levels of Zr. Fe-rich impurities present in most sands, are responsible for the pale green color of naturally colored glass. The levels and nature of impurities present in silica sources also reflect their oldness and depositional history, this is particularly true for titanium, neodymium, and zirconium (Henderson 2013:60-61, 64).

Trace elements and rare earth elements (REEs) present in sands can provide some information that can be useful to determine provenance. For instance, the concentration of two particular REEs, europium (Eu) and cerium (Ce), relative to other REEs can reflect the conditions of the chemical system and geological processes in which the minerals containing them were formed (Henderson 2013:57-59). In addition to REEs, some other elements found in trace quantities can also be useful to determine provenance. Researchers studying the spread of Venetian style glass (Šmit et al. 2004:720) have used zirconium (Zr) and hafnium (Hf) to distinguish glass production centers since they are tracers of the sand that was used as raw material for glassmaking.

Glassmakers were undoubtedly aware of variable sand qualities and would have carefully selected silica sources depending on the type or quality of glass they wanted to produce. Washing and sieving the sand helps remove impurities of the sand, but in some cases, glassmakers used purer forms of silica. In the fourteenth century, for example, Venetian glassworkers used crushed quartz pebbles as a vitrifying source that was purer than the sands from inland regions. Quartz pebbles had to be burnt in a furnace and quenched in water to be crushed and ground but, while time consuming, the process resulted in a quartz powder that was purer than natural sands. Fritting and grinding also facilitate the fusion of the raw materials, although at sufficiently high temperatures this step would have been unnecessary (Henderson 1985:271; 2013:61; Moretti and Hreglich 2013:29; Rehren and Freestone 2015:234).

In the case of New Spain, historical documents provide few clues on the origin of the sands used for glassmaking. As mentioned in Chapter 6, the only places referred to in historical records regarding sand collection are Tlalpujahua, Michoacán (Humboldt 1966 [1822]:459), and possibly the Ventas de Perote, Valley of Temaxcalapa, Veracruz (Gerhard 2000:387; Gómez Pastor and Fournier 2001:46), while Jáltipan, Veracruz may have been another option given the presence of high quality sands (Melgarejo Vivanco 1960:237). The records of both the Casa del Apartado and Doña Micaela's workshop sometimes include *arena de pedernal* or flint sand, *ground flint*, and in one instance, *arena de marmol* or marble sand.[251] These were in addition to the trips of sand that were brought to both places on a regular basis, as mentioned in Chapter 6, suggesting that different sources of silica were exploited and used for glassmaking.

#### 8.1.2. Network modifiers (flux): Alkalis

In addition to lowering the melting point of silica, the flux helps make glass mixtures more easily fusible. Soda makes glass "longer," meaning that it takes it longer to solidify and, thus, can be manipulated by the glassmaker for a longer period. However, an excess of soda makes the glass more susceptible to humidity, leading to a more rapid decay. Three main alkali sources were used in the past as a flux in the Western world: halophyte plant ashes, potash plant

[251] AGN, Civil, vol. 350, exp. 2, f.182.

ashes, and evaporite minerals such as trona and natron (Moretti and Hreglich 2013:29). In the case of New Spain, historical records indicate that two of these were used; sodium plant ashes and the evaporite-*based alkalis.*

8.1.2.1 Plant Ash

Plant ashes have been used as a source of alkali since the earliest glasses were made. It was the dominated alkali in the old world until about 800 BCE, and then again after 800 CE after a period in which the evaporite-based alkali natron was preferred. A wide variety of plants can be used as a source of alkali for glassmaking and include both halophyte plants and the so-called forest plants used in central Europe which encompass a variety of alkaline plants such as oak, beech, pine, and bracken (Henderson 2013:23, 48). As mentioned in Chapter 6, the Spanish tradition of glassmaking was based on the use of halophyte plants as the source of alkali, and the historical documents from Mexico indicate that the same was true for New Spain. For this reason, the discussion will center only on halophyte plants.

The salt-tolerant plants that provide the source of alkali grow in semi-desert environments, in saline maritime environments, and around inland brackish waters. When the plants are burned the alkalis form a significant part of the resulting ashes. Also mentioned in Chapter 6 was the need for these alkalis (Na and K) to be present primarily in the form of carbonates, bicarbonates, sulfides, sulfites, and hydroxides, as opposed to either chlorides or sulfates (Tite et al. 2006:1285). A crucial compound in the plant to be suitable for glassmaking: sodium carbonate ($Na_2CO_3$), which is a strong fluxing agent that lowers the melting point of glass formers (like silica), as well as the viscosity and surface tension of the melt. Sodium chloride and potassium chloride are also present in plant ashes, but they react very slowly prior to decomposition (for sodium sulfate this happens around 1200ºC) and their interaction with silica is minimal. These compounds, together with sodium sulfate, tend to volatilize or be eliminated from the glass melt as scum (Henderson 2013:23; Tite et al. 2006:1285). Plant ashes can also introduce calcium, magnesium, potassium, iron and aluminum into the melt (Freestone 1991:40-41; Henderson 2013:43). Of the wide variety of halophytic plants of the Chenopodiaceae family that are suitable alkali sources for making glass, two particular species were proposed based on their characteristics and distribution: *Suaeda edulis* and *Suaeda pulvinata*, both of which concentrate alkaline salts in their succulent leaves.

Halophyte plants that provide a suitable source of alkali are affected by the geochemistry of the soil and the ground water in which they grow. Relative levels of calcium (Ca), strontium (Sr), boron (B), and phosphorous (P) seem to be the most sensitive indicators of variations in the underlying geology (Henderson 2013: 312). In addition, the composition of the plant ashes is also determined by other factors including: the plant species, the stage in the growing season in which it was collected, the part of the plant used (stems or leaves), and the process followed to process them into ashes (Tite et al. 2006:1285). As the relative levels of each element could affect the characteristics of the glass, a certain degree of predictability in the composition of the ashes was necessary. For instance, the concentrations of calcium and magnesium in the glass melt would increase the melting temperature, resulting in a "short" glass that gets rigid more rapidly (Henderson 2013:36). Glassmakers would have thus preferred the use of specific plants growing in a particular location and harvested at a particular season and stage of growth that they knew produced consistently good quality glass. This might explain why the *barrilla* from certain areas, like Michoacán in the seventeenth century, was deemed better from the one collected in other regions; it also explains why an ordinance was put in place to restrict the collection of *barrilla* when it was young.

8.1.2.2 Evaporite-based alkali

Between 800 BCE and 800 CE, a shift in the preference of alkali took place in the old world, when the evaporite natron became the preferred source of alkali. This component provided a relatively pure source of alkali, and became the main fluxing agent for the glass made in the Roman Empire (Henderson 2013:51). While natron glass has similar levels of soda as that made with plant ash, it usually has less than 1.5 wt% levels of each magnesia and potash. It is formed seasonally and is easily collected in the dry season from alkali-rich lakes. The glass made with natron may have behaved in a more predictable way when worked, stimulating its use in the West and Middle East (Henderson 2013:51-52; Rehren and Freestone 2015:234).

*Tequesquite* was the New World equivalent to natron. A recent study characterized the chemical composition of samples of this evaporite collected in Lake Texcoco (Flores-Hernández and Martínez-Jerónimo 2016). As mentioned in Chapter 6, *tequesquite* is also collected in Puebla/Tlaxcala in the lagoon of Totolcingo. Halophytic plants similar to those growing around Lake Texcoco also grow in this area. Considering that this lagoon is closer to Puebla, and that it has similar resources as those in Texcoco, it is possible that the area represented a source of raw materials for the glassmakers of Puebla.

*Tequesquite* is an alkaline salt-rich product formed from the evaporation and crystallization of brackish waters of some lagoons in the valley of Mexico, Puebla, Jalisco, and Chihuahua, which are notable for having high contents of sodium carbonates (Flores 1918:1; Flores-Hernández and Martínez-Jerónimo 2016:31). During the dry season, the salinity of the natural water outcrops can reach levels of up to 90 g/L causing salt crusts to form on the dried-out lake surface. These salt crusts or *tequesquite*, represent a resource that has been exploited in Mexico since prehispanic times. *Tequesquite* can vary in color and quality depending on its purity and clay content (Flores-Hernández and Martínez-Jerónimo 2016:32). In the early twentieth century, *tequesquite* was classified for its popular use into five types depending on its color, texture, and purity: 1) *confitillo*, a white material with the appearance of a cauliflower; 2) *cascarilla* or *tepalcatillo*, which was crusty; 3) *espumilla*, which was collected from the foam of brackish water; 4) *polvillo* or *cristalillo*, which was powdery, and 5) *tequesquite prieto*, the most impure, mixed with clay or fine sand (Flores 1918:7). The major components of *Tequesquite* are sodium chloride (NaCl) and sodium carbonates, primarily trona ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$), a double-hydrate carbonate and bicarbonate salt that is formed by evaporation and concentration of water containing high $Na^+$ and $HCO_3^-$, as well as lesser amounts of other carbonates, chlorides, and sulfates (Flores-Hernández and Martínez-Jerónimo 2016:35-36, 38; Stoner et al. 2014:870). These salts can be mixed with quartz, feldspars, clays, and other minerals depending on the type and amount of incorporated soil which in terms of elemental composition also translates into higher levels of silicon (Si), aluminum (Al), magnesium (Mg) and iron (Fe). Flores-Hernández and Martínez-Jerónimo (2016:33) analyzed four samples of *tequesquite* and found that the most abundant component was the sodium ion followed by potassium, carbonates, and bicarbonates at similar concentrations, as well as trace amounts of phosphates and nitrates. Remainder content included insoluble particles (clay and sand), moisture, as well as sulfur and chlorine. In terms of the crystal structure, the four samples analyzed showed similar diffraction patterns, suggesting that they have the same chemical footprint, but may differ in the relative abundance of the components as well as on the amount of impurities, which proportionally reduce the amount of other chemical compounds (Flores-Hernández and Martínez-Jerónimo 2016:35-36, 38).

### 8.1.3. Network stabilizer

An essential component in glass is the network stabilizer, a calcium (Ca)-rich compound like calcium carbonate ($CaCO_3$) or calcium oxide (CaO) which reduces the solubility of the glass, making it stronger and more durable. Without this component, glass can easily deteriorate under humid conditions. Calcium provides glass durability but if present in excessive amounts it increases the melting temperature of the batch. Sources of calcium include: 1) shell fragments present in sands or added deliberately to the batch; 2) calcium present in the plant ashes; 3) dolomitic limestone, which would produce a positive correlation between calcium and magnesium oxides in the glass; and 4) bone fragments (Henderson 1985:277; 2013:64-65). Alumina and alkaline earth metals can also act as stabilizers. Alumina can come from sand impurities such as feldspar and clay and from non-purified plant ashes. Ashes containing calcium and magnesium carbonates can also introduce calcium and magnesium oxide, which also acted as stabilizers (Moretti and Hreglich 2013:30).

One of the expense records of Doña Micaela's furnace included the purchase of seventeen loads of lime,[252] but it is not certain if this material was used for glassmaking because the report also accounted for the expenses to repair the ceilings, so it is possible that the lime was bought for that purpose. Since the records from the Casa del Apartado do not mention lime, it is most probable that calcium came from the use of plant ashes or may be was a component of the sands.

[252] AGN, Civil, vol. 350, exp. 2, f. 119v.

### 8.1.4. Additives: Colorants, Opacifiers, and Decolorizers

In addition to the three main components –network former, network modifier, and network stabilizer – other components can be added to the glass melt to impart color, to opacify translucent glass, or to decolor naturally colored class (from impurities).

#### 8.1.4.1. Colorants

The main compounds used in the past for the coloration of glass, both transparent and opaque, include the oxides of only seven metals: copper, cobalt, tin, antimony, lead, manganese, and iron (Rehren and Freestone 2015:235). The final color of glass does not depend solely on the choice of a chemical colorant, but on numerous other factors. Transition metal ions like chromium ($Cr^{2+}$), manganese ($Mn^{2+}$, $Mn^{3+}$), iron ($Fe^{2+}$, $Fe^{3+}$), copper ($Cu^{+}$, $Cu^{2+}$), and cobalt ($Co^{2+}$) can produce deep colors in translucent glass. The resulting color is contingent to their concentration, chemical environment, and relative strength of absorption coefficients. Other factors affecting the color include: 1) the preparation of the glass batch, using finely ground colorant materials and thoroughly mixing the glass batch will reduce color streaking; 2) the maximum temperature reached: high melting temperatures ensure the dissolution of the colorant in the melt; 3) the atomic weight of the alkali: larger atomic numbers will produce darker hues; 4) the gaseous atmosphere in the furnace at different points in the melting cycle: reducing or oxidizing; 5) the chemical environment, that is, the arrangement of surrounding ions; 6) the nature of the heating cycle: using different types of fuel to achieve particular temperatures; and 7) the presence of crystalline opacifiers (Henderson 2013:65-68).

The coloring elements can be introduced using various raw materials, for example, an unrefined mineral ore bearing the colorant element but in association with others; a mineral ore that has been processed (e.g. crushed, washed, and roasted); a colorant frit,[253] as well as glass cullet, cakes, or canes of highly colored glass. Using a frit, cullet, glass cakes or canes enabled the glassmaker more control over the resulting color than using raw minerals (Henderson 1985:278).

In terms of the mineral oxides used to color glass, cobalt oxide (CoO) was used to produce blue; copper oxide (CuO) for turquoise to green, cuprous oxide ($Cu_2O$) for red; and manganese oxide ($Mn^{3+}$ and $Mn^{4+}$) for purple. Iron oxide ($Fe^{3+}$) can produce a variety of colors including green, yellow, brown, and black depending on the furnace atmosphere (Freestone 1991:42-43; Henderson 1985:278-284). A golden-amber color can come from the presence of both iron and sulfide ions in glass melted under strongly reducing conditions, while high concentrations of FeO and $MnO_2$ in thick glass can make it look black even if the glass is translucent (Möncke et al. 2014:33, 35-36). Another possible colorant of glass is bronze. When copper (Cu), lead (Pb), and tin (Sn) occur in fixed ratios leaded bronze scraps may have been added to the batch to produce turquoise glass (Freestone 1991:43; Henderson 1985:282).

We know from traveler descriptions that in Puebla, as early as 1547, at least three different types of glass were made: blue, green, and crystalline white or colorless (Fernández 1990:227). From the eighteenth-century records of Doña Micaela's workshop we know that she sometimes acquired two colorants, mostly blue but once she purchased purple. As mentioned above, the iron impurities in the sand normally render glass in aquamarine or green color. A

[253] A colorant frit is a calcined mixture of the colorant oxide and other raw materials (sand and fluxes).

deeper darker blue tone can be achieved by adding cobalt oxide to the melt. In the case of purple, the most likely candidate would be manganese.

8.1.4.2. Decolorizers

Given the presence of iron impurities in sands, glass normally comes in a green or turquoise color. But the desire to make colorless glass has acquired importance at different periods since Roman times. In addition to function as a colorant, manganese can also act as a decolorizer through redox reactions. $Mn^{4+}$ in the form of manganese dioxide ($MnO_2$) or $Mn^{3+}$ act as oxidizing agents for the $Fe^{2+}$ (ferrous ions) in the aqua-blue glass, producing ferric ions ($Fe^{3+}$) and $Mn^{2+}$ which create the colorless effect (Henderson 1985:284; 2013:76; Rehren and Freestone 2015:235). Two possible reactions can occur between iron and manganese depending on the species of Mn:

$$Mn^{4+} + 2Fe^{2+} \rightarrow Mn^{2+} + Fe^{3+}$$

$$Mn^{3+} + 2Fe^{2+} \rightarrow 2Mn^{2+} + Fe^{3+}$$

Manganese also decolorizes by leveling out the selective absorption of the optical spectra. For instance, when the blue $Fe^{2+}$ absorption bands combine with those of purple $Mn^{3+}$ no wavelengths are absorbed more strongly than others, so no distinct color is apparent, although thick samples may show a greyish hue (Möncke et al. 2014:35). When $MnO_2$ is present in quantities between 0.3-0.8% it is considered that it was used as a decolorizer because when present in higher quantities it makes the glass purple (Moretti and Hreglich 2013:32).

Another glass decolorizer is antimony (Sb) which, like manganese, oxidizes the iron to its yellowish form, giving the impression of a colorless glass. Antimony is more effective than manganese and also acts as a fining agent[254] that produces a more brilliant colorless glass. The glassmakers in Venice seem to have controlled the firing conditions in order to produce colorless glass (Bidegaray et al. 2019; Henderson 1985:284; 2013:76; Jackson 2005:764). According to Gliozzo (2017:468), for a glass to be considered decolorized by the addition of Sb it should have levels of MnO below 0.25 wt% and Sb higher than 100 ppm.

Obtaining colorless glass would have been desirable in colonial Mexico in different ways. Firstly, to produce fine glass objects in imitation of those incoming from Europe, such as Venetian *cristallo*, Catalan or Castilian glass *à la façon de Venise*, and later, engraved Bohemian glass or glass from the royal factory of La Granja de San Ildefonso. Puebla in particular, seems to have been a place where making fine glass objects may have been attempted, considering the praise given by several travelers of the glass objects made there. Colorless glass would also have been desirable for glass artisans in Mexico City who specialized in the making of ophthalmic lenses.

#### 8.1.4.3. Opacifiers

Glass opacification is produced by the presence of inclusions or crystals which reflect wavelengths of light instead of transmitting them as it occurs in translucent glasses (Henderson 2013:77). There are two main glass opacifiers: tin and antimony. Tin can produce opaque white when present as tin oxide ($SnO_2$), and opaque yellow when forming a compound with lead ($Pb_2SnO_4$ or $Pb_2Sn_2O_7$) . Antimony reacts differently depending on the type of glass: in lead-containing batches and under oxidizing conditions, antimony produces opaque yellow crystals of lead pyroantimonate ($Pb_2Sb_2O_7$), which remain undissolved; in soda-lime-silica glasses,

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[254] Fining agents facilitate the removal of gas bubbles from molten glass and to homogenize the glass during the melting process (Moretti and Hreglich 2013: 31).

antimony can react with calcium producing opaque white crystals of calcium antimonate ($Ca_2Sb_2O_6$ or $Ca_2Sb_2O_7$). However, the color and opacification can be annulled in both lead-tin and lead-antimony opacified glasses if the heat reaches temperatures above 1000ºC – 1100ºC. In addition to tin and antimony, there are other compounds that function as opacifiers like arsenic oxides ($As_2O_3$ or $As_2O_5$) in conjunction with lead and fluorides, or cuprous oxide ($Cu_2O$) and iron which result in an opaque red glass (Henderson 1985:285-286; 2013:77). At the end of the seventeenth century, lead arsenate ($3Pb_3(AsO_4)PbO$) was used to make opaque white glass and in the nineteenth century, calcium fluoride was used for the same purpose in Italy. At this time, other opacifiers began to be used including calcium antimonate ($Ca_2Sb_2O_7$) and calcium stannate ($CaSnSiO_5$) (Henderson 2013:78-79).

There are other ways in which glass can be opacified that do not require the addition of opacifying agents. Glass can turn opaque when there is incomplete vitrification, resulting in the presence of crystalline soda-lime-silicates in the glass, or when these crystals form by subsequent devitrification. Another form of glass opacity derives from masses of air or gas bubbles or impurities in the glass (Henderson 1985:286).

## 8.2. Analysis of Local Alkali: Mexican Plant Ashes and *Tequesquite*

As discussed in Chapter 6, colonial glassmakers in the eighteenth century had two types of alkali in the workshops: *barrilla* and *tequesquite*. Given the composite nature of both plant ashes and *tequesquite*, analyzing these materials and interpreting the results can be challenging, however, the information obtained from these studies is important to detect their presence in archaeological glass and to better understand the technology used in colonial Mexico.

8.2.1. Plant Ashes

One way to investigate the use of plant ashes in glassmaking is first to analyze the chemical composition of the ashed halophyte plants. This information can be used for three purposes: 1) to determine which genus or species is suitable for making glass; 2) to assess to what degree the composition of the ashes was transferred into the glass; and 3) to investigate if the soil geochemistry in which the plant grew is reflected in the glass, providing potentially provenance information. However, the relationship between the chemical composition of plant ashes and that of the resulting glass is affected by a number of factors. Variations in the drift and bedrock geologies in which plants grow, for instance, can affect the chemical and mineralogical composition of the plant ashes; and different plant species can differ in composition even if they grow in the same area. The way in which the plants are processed can also result in different compositions; these include mixing together different plant species, the temperature of calcination, as well as the purification of the ashes by dissolution, distillation, and recrystallisation (Henderson 2013:25). In Venice, for instance, plant ashes were purified to remove unwanted constituents such as insoluble salts and obtain a white crystalline salt (Jacoby 1993:68). Moreover, the melting conditions under which the glass is made will have an effect in the final composition of the glass. Nevertheless, soda glass made with plant ashes tends to present elevated levels of magnesium and potassium oxide (Henderson 2013:25-26).

To investigate the use of endemic halophytes, two species discussed in Chapter 6, *Suaeda edulis* (Figure 129a) and *Suaeda pulvinata* (Figure 129b), were collected in both the dry and wet seasons from the lagoons of Cuitzeo, Michoacán; Sayula, Jalisco; Texcoco, Estado de México; and Totolcingo, Puebla/Tlaxcala (Figure 130). After drying, the plants were fired twice (Table 6).

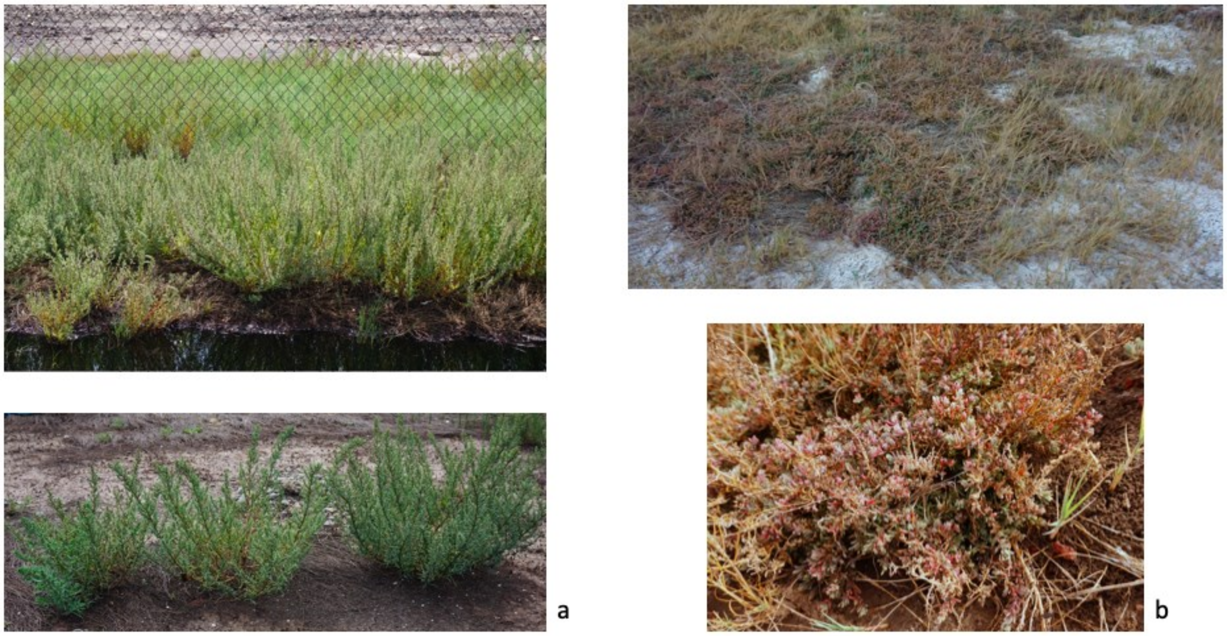



Figure 129. Halophyte plants from Texcoco, Estado de México: a) Suaeda edulis (rainy season); b) Suaeda pulvinata (dry season) (photos: Karime Castillo).

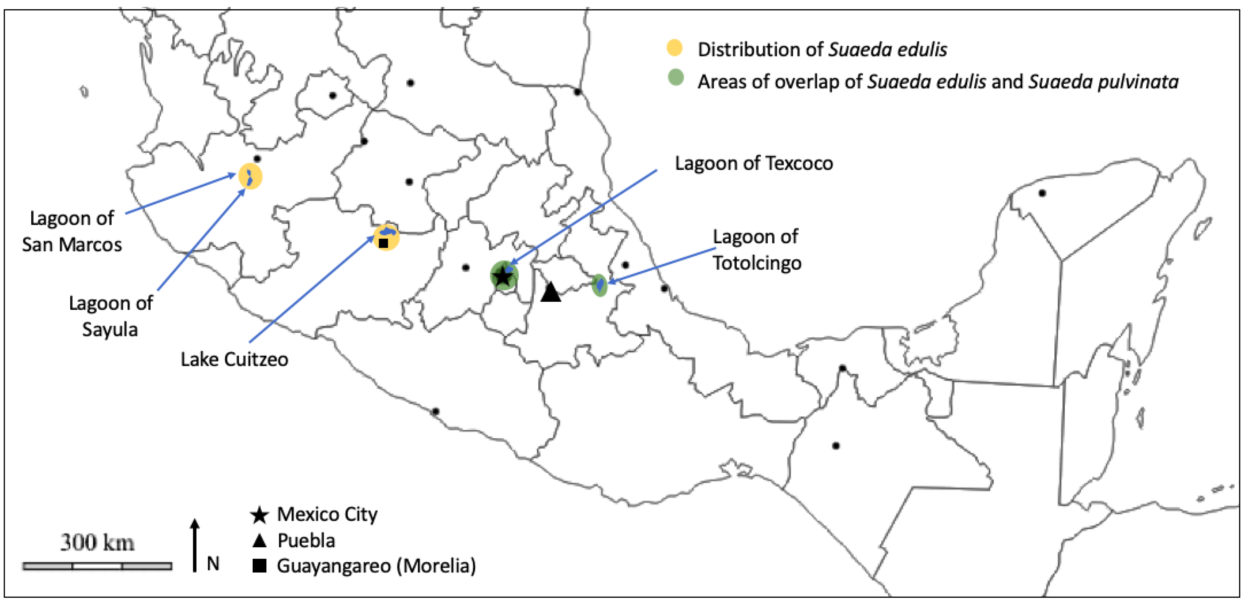



Figure 130. Brackish lagoons of Mexico where halophyte plants and tequesquite/salt efflorescence were collected.

Table 6. Ash weight (in grams) obtained after the first (300°C) and second (700°C) firing from samples of *Suaeda edulis* and *Suaeda pulvinata* collected during the 2018 summer (wet season) and winter (dry season) in Mexico.

| Sample | Species | Provenance | Location | Collection season | First firing (300°C) | Second firing (700°C) |
|---|---|---|---|---|---|---|
| Ash-01 | *Suaeda pulvinata* | Cuitzeo, Michoacán | 19°54'31.4" N 101°09'21.3" W | Summer | 30.087 | 7.086 |
| Ash-02 | *Suaeda pulvinata* | Totolcingo, Puebla/Tlaxcala | 19°18'34.5" N 97°37'13.7" W | Winter | 40.518 | 30.092 |
| Ash-03 | *Suaeda edulis* | Texcoco, Estado de Mexico | 19°28'29.3" N 98°59'24.8" W | Winter | 14.423 | 6.859 |
| Ash-04 | *Suaeda pulvinata* | Sayula, Jalisco | 20°07'35.2" N 103°30'30.3" W | Summer | 29.776 | 9.105 |
| Ash-05 | *Suaeda edulis* | Totolcingo, Puebla/Tlaxcala | 19°18'20.6" N 97°36'25.9" W | Summer | 20.095 | 8.286 |
| Ash-06 | Suaeda *edulis* | Texcoco, Estado de Mexico | 19°28'36.0" N 98°59'07.4" W | Summer | 3.691 | 1.684 |

The composition of the plant ashes was investigated with SEM-EDS on pressed pellets. Micrographs taken in backscattered electron (BSE) mode show the compositional heterogeneity of the material based on compositional contrast with higher-Z elements appearing brighter white in the images. Both grey areas correspond to phases enriched in low-Z elements such as C, Na and Mg while the brighter ones contain higher-Z elements such as Ca, K, and Cl (Figure 131). The variation in brightness provides therefore an indirect estimate of the phases which are present in each sample. Compositional data were collected on five areas similar to the ones shown in Figure 131 and averaged (Table 7).

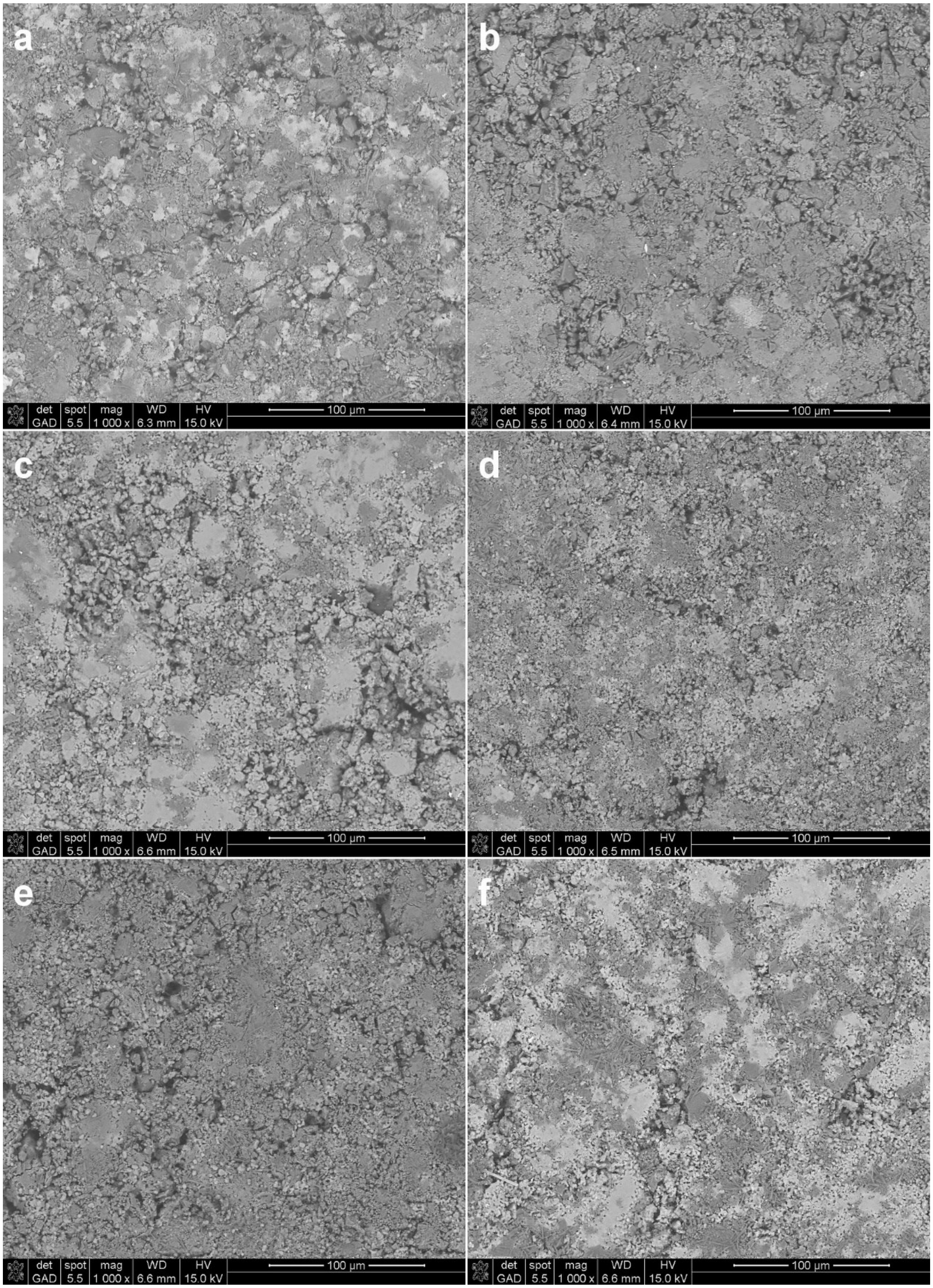



Figure 131. SEM micrographs of plant ashes obtained from Mexican *barrilla*. (a) Ash-01, (b) Ash-02, (c) Ash-03, (d) Ash-04, (e) Ash-05, (f) Ash-06.

Table 7. Chemical composition (SEM-EDS) of the ashes obtained from the potential barilla plants collected in Mexico (elements in oxides, wt%).

| Sample | $CO_2$ | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $SO_3$ | Cl | $K_2O$ | CaO | $TiO_2$ | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash-01 | 18.02 | 29.97 | 3.79 | 1.55 | 16.02 | 1.59 | 2.50 | 7.66 | 9.29 | 7.87 | 0.24 | 1.50 |
| Ash-02 | 8.54 | 14.92 | 6.07 | 7.21 | 32.06 | 1.11 | 4.38 | 8.33 | 2.52 | 12.57 | 0.19 | 2.22 |
| Ash-03 | 14.18 | 34.01 | 2.45 | 1.78 | 6.97 | 1.35 | 5.60 | 25.78 | 3.95 | 2.38 | 0.25 | 1.41 |
| Ash-04 | 10.81 | 29.04 | 2.95 | 3.79 | 17.17 | 1.36 | 4.11 | 14.79 | 5.83 | 7.52 | 0.27 | 2.43 |
| Ash-05 | 13.63 | 26.58 | 4.82 | 3.63 | 21.50 | 1.61 | 5.90 | 10.60 | 5.16 | 4.71 | 0.26 | 1.75 |
| Ash-06 | 12.46 | 31.95 | 1.17 | 2.00 | 8.90 | 2.38 | 5.77 | 22.54 | 9.15 | 2.19 | 0.20 | 1.40 |

The samples contain significant amounts of alkali (Na and K) and alkaline earth (Mg and K), as well as chlorine (Cl), sulfur (S) and phosphorus (P) in concentrations consistent with published data for ash composition obtained from halophyte plants in the old world (Barkoudah and Henderson 2006; Tite et al. 2006). The high levels of silicon and lesser amounts of aluminum and iron are mainly due to soil and/or dust contamination.

8.2.2. *Tequesquite*

The second fluxing agent mentioned in the historical documents is *tequesquite*, an alkaline mineral complex that is formed through the evaporation and crystallization of brackish and alkaline athalassohaline lakes, which are characterized by a high content of sodium carbonate or other compounds of this salt (Flores-Hernández and Martínez-Jerónimo 2016). In Mexico, these type of lakes can be found in the basin of Mexico, Puebla/Tlaxcala, Michoacán, Jalisco, Chihuahua, and Coahuila (Forshag 1936:141). Salt efflorescence/*tequesquite* samples were obtained from the same areas where the halophyte plants were collected during the dry season (

Figure 132). Most samples were salt efflorescence mixed with soil (Table 8), but one (TLX-01) was collected during the harvest of *tequesquite* at El Carmen Tequexquitla, Puebla (Figure 133) while another one (MRK-01) sold as *tequesquite was* purchased at the Mercado de San Juan in Mexico City.

Figure 132. The Lagoon of Totolcingo, Puebla/Tlaxcala in the dry season showing the dry bed of the lagoon covered in salt efflorescence (photo: Karime Castillo).

Table 8. Samples of salt efflorescence and *tequesquite* collected during the dry season.

| Sample name | Type | Provenance | Location |
|---|---|---|---|
| LSM-01 | salt efflorescence | Lagoon of San Marcos, Jalisco | 20°14'37.2" N 103°32'20.6" W |
| LS-01 | salt efflorescence | Lagoon of Sayula, Jalisco | 20°07'35.2" N 103°30'30.3" W |
| TEX-01 | salt efflorescence | Texcoco, Estado de Mexico | 19°28'29.3" N 98°59'24.8" W |
| EC-01 | salt efflorescence | El Carmen Tequexquitla, Tlaxcala (Lagoon of Totolcingo) | 19°18'34.5" N 97°37'13.7" W |
| PE-01 | salt efflorescence | Patrimonio Ejidal, Oriental, Puebla (Lagoon of Totolcingo) | 9°22'00.3" N 97°35'42.7" W |
| LC-01 | salt efflorescence | Lagoon of Cuitzeo, Michoacán | 19°54'31.4" N 101°09'21.3" W |
| LT-01 | salt efflorescence | Lagoon of Totolcingo, Puebla/Tlaxcala | 19°18'20.6" N 97°36'25.9" W |

| | | | |
|---|---|---|---|
| TLX-01 | *Tequesquite* (*confitillo*) | El Carmen Tequexquitla, Tlaxcala (Lagoon of Totolcingo) | 19°18'53.2" N 97°37'53.9" W |
| MRK-01 | *Tequesquite* (*cascarilla*) | Mercado de San Juan, Mexico City (Texcoco?) | n/a |

Figure 133. Tequesquite harvest: a) community members of El Carmen Tequexquitla, Tlaxcala, collecting tequesquite; b) water canals to intensify the production of tequesquite; c) detail of tequesquite crusts (photos: Karime Castillo).

Elemental composition was determined with SEM-EDS analysis on pressed pellets (Table 9). Due to the low amounts of Na and high Al and Si, samples LT-01and LSM-01 will not be considered for further analysis as aluminosilicate phases are predominant. Sample LS-01 seems to be contaminated with titanium oxide (sample collected near a highway) and will be excluded as well. For the rest of the samples, in can be seen in Table 9 that sample TLX-01 shows the highest levels of Na and C (most likely associated with carbonates), while samples

TEX-01 and MRK-01 are Cl-rich. In addition to Na and C, sample LC-01 contains Al, Si, S, Ca, and Fe, indicating the presence of quartz, aluminosilicates, sulfates, and calcite in significant amounts.

Table 9. Elemental composition of the salt efflorescences/*tequesquite* samples analyzed with SEM-EDS (elements in oxides, wt%).

| **Sample** | **$CO_2$** | **$Na_2O$** | **MgO** | **$Al_2O_3$** | **$SiO_2$** | **$P_2O_5$** | **$SO_3$** | **Cl** | **$K_2O$** | **CaO** | **$TiO_2$** | **$Fe_2O_3$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEX-01 | 17.41 | 33.78 | 1.22 | 5.06 | 15.66 | 1.06 | 5.76 | 15.21 | 2.52 | 0.73 | 0.20 | 1.47 |
| MRK-01 | 18.82 | 31.80 | 1.19 | 6.06 | 16.40 | 0.91 | 4.79 | 12.88 | 3.59 | 1.35 | 0.30 | 1.98 |
| TLX-01 | 39.25 | 48.94 | 0.42 | 0.64 | 3.16 | -:- | 2.02 | 3.10 | 2.13 | 0.55 | -:- | -:- |
| LT-01 | 15.46 | 5.18 | 6.30 | 11.20 | 51.42 | 0.01 | -:- | 0.18 | 2.57 | 5.06 | 0.35 | 2.34 |
| EC-01 | 22.08 | 35.28 | 1.01 | 2.59 | 12.59 | 0.37 | 14.48 | 5.12 | 2.52 | 3.20 | -:- | 0.76 |
| LSM-01 | 15.88 | 7.40 | 1.27 | 11.78 | 53.26 | 0.05 | -:- | 0.25 | 1.86 | 2.30 | 0.81 | 5.17 |
| LS-01 | 16.85 | 19.36 | 3.44 | 11.06 | 30.74 | 0.23 | 1.28 | 3.52 | 2.57 | 4.11 | 2.98 | 3.92 |
| PE-01 | 21.81 | 33.93 | 0.96 | 3.38 | 15.56 | 0.27 | 13.75 | 3.46 | 2.15 | 4.02 | -:- | 0.75 |
| LC-01 | 13.44 | 15.40 | 2.01 | 7.26 | 31.97 | 0.29 | 15.64 | 1.33 | 1.83 | 7.28 | 0.62 | 3.18 |

-:- : below detection limit.

In order to further explore the composition of this alkali source, the powders were analyzed using Fiber Optics Reflectance Spectroscopy (FORS). In the visible spectral range (400-700 nm), the overall reflectance varies between the samples with significant absorptions for TEX-01, MRK-01, and LC-01. These are related to traces of iron oxides and oxyhydroxides, probably associated with clay phases. This is also consistent with the slightly darker tone of the corresponding powders. On the other hand, reflectance is intermediate for PE-01 and EC-01, and the highest for TLX-01 (Figure 134).

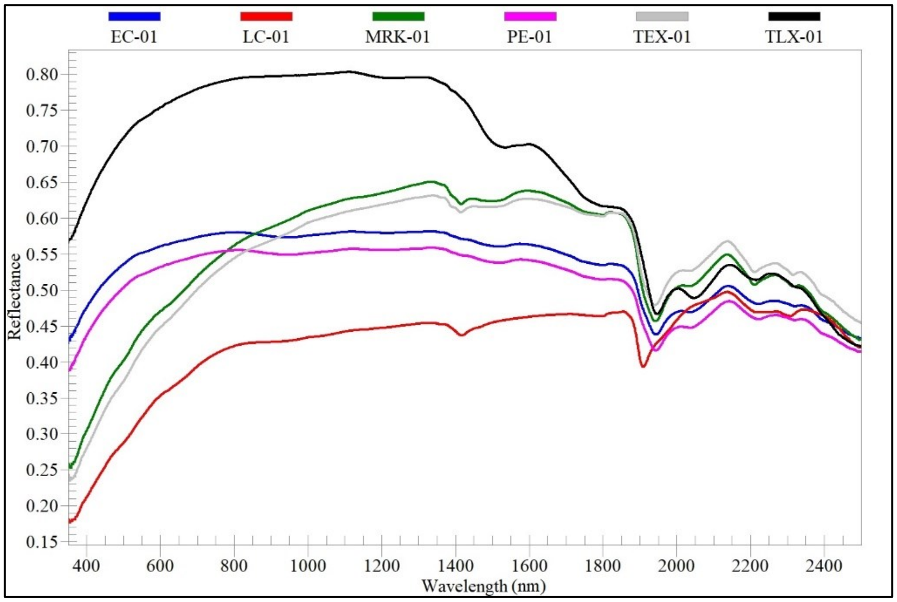



Figure 134. FORS reflectance spectra of the different salt efflorescence/*tequesquite* samples.

The major absorptions resulting from the presence of salt phases, however, occur in the near infrared range, in particular above 1500 nm. Specific absorptions characteristic of trona, a non-marine evaporite mineral with formula $Na_3H(CO_3)_2{\cdot}2H_2O$ can be identified at ~ 1510, 1940, 2042, 2221, and 2390 nm (Harner and Gilmore 2015) (Figure 135 left). The position of these absorptions is clearer when plotting the 2nd derivative in which they appear as positive peaks (Figure 135 right). These absorptions correspond to overtones and combination bands associated with the structural water and carbonate ions (Cloutis et al. 2006; Crowley 1991). Based on their relative intensities, sample TLX-01 seems to be mainly composed of trona, a result consistent with the EDS analysis.

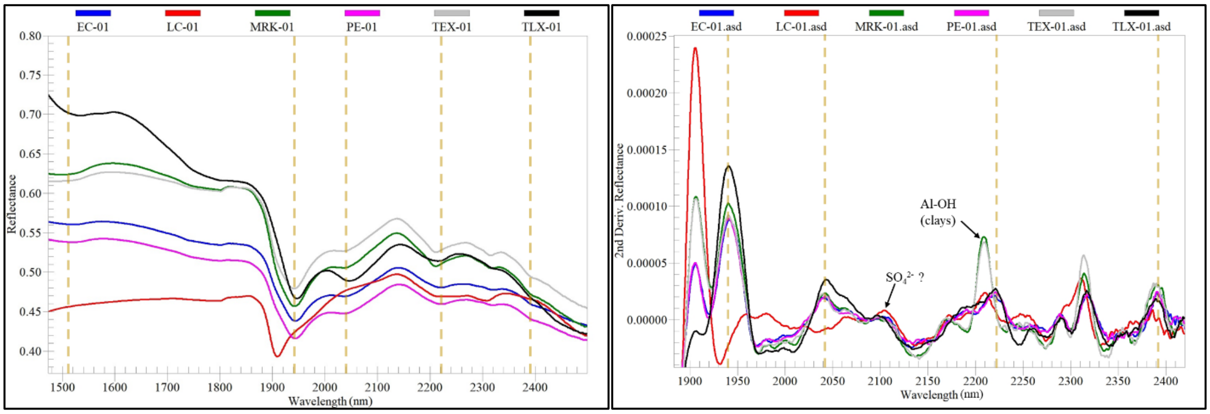



Figure 135. Detail of the NIR spectral range with the vertical dashed lines showing the position of the characteristic absorptions for trona (left: reflectance spectra; right: 2nd derivative).

Also noticeable are the absorptions at about 2100 nm which could indicate the presence of sulfates (Cloutis et al. 2006) and at 2208 nm (combination band Al-OH) due to the presence of clay minerals. The strong absorption at about 1905 nm is due to water adsorbed on the surface of clays and/or associated with some hygroscopic salt phases such as halite.

The presence of trona was confirmed by XRD which also identified halite as a main component as well as other sulfate and carbonate salts and lesser amounts of calcite, quartz, and aluminosilicates (Figure 136). Sample TLX-01 is the most salt-rich material and mainly composed of trona associated with some halite and thermonatrite ($Na_2CO_3 \cdot H_2O$), while halite is predominant in samples TEX-01 and MRK-01. Samples EC-01 and PE-01 contain slightly less trona but more halite as well as quartz and feldspars, and more importantly, thenardite, an anhydrous sodium sulfate ($Na_2SO_4$). This latter phase is also a significant component of sample LC-01 alongside feldspars, some trona and calcite, and traces of halite. For samples LC-01, EC-01 and PE-01, the presence of thenardite is consistent with the high levels of sulfur measured with EDS (Table 9). Overall, XRD results are consistent with the elemental composition obtained with EDS analysis as well as with published data on *tequesquite* (Flores-Hernández and Martínez-Jerónimo 2016).

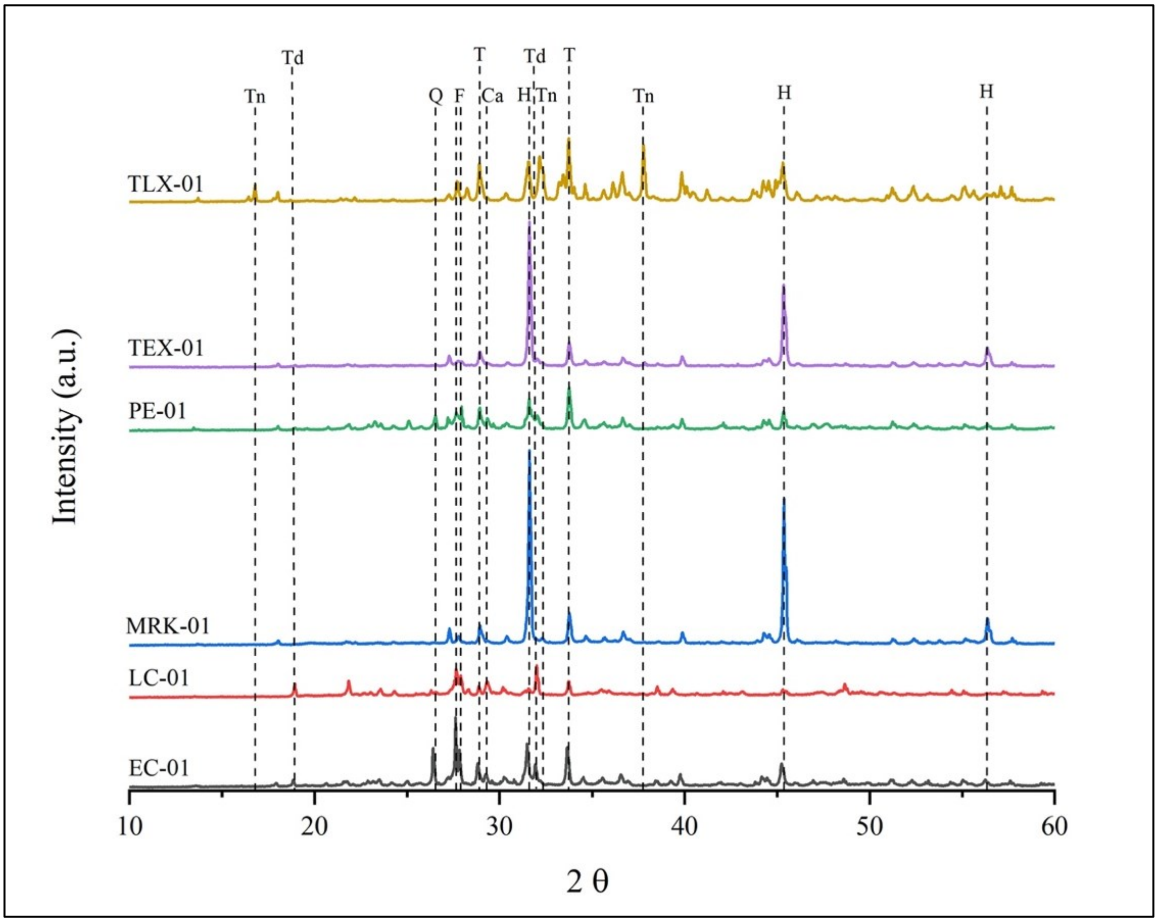



Figure 136. XRD patterns of the salt efflorescence/*tequesquite* samples showing the presence of various mineral phases (T: trona, H: halite, Td: thenardite, Tn: thermonatrite, Ca: calcite, F: feldspars, and Q: quartz).

The various phases composing these salt efflorescence and *tequesquite* can also be observed with SEM imaging, either on pressed pellets in BSE mode which allows to differentiate them based on composition (Figure 137), or in secondary electrons mode on the powder for a 3D visualization of their morphology such as the columnar and prismatic habit characteristic of trona crystals (Figure 138).

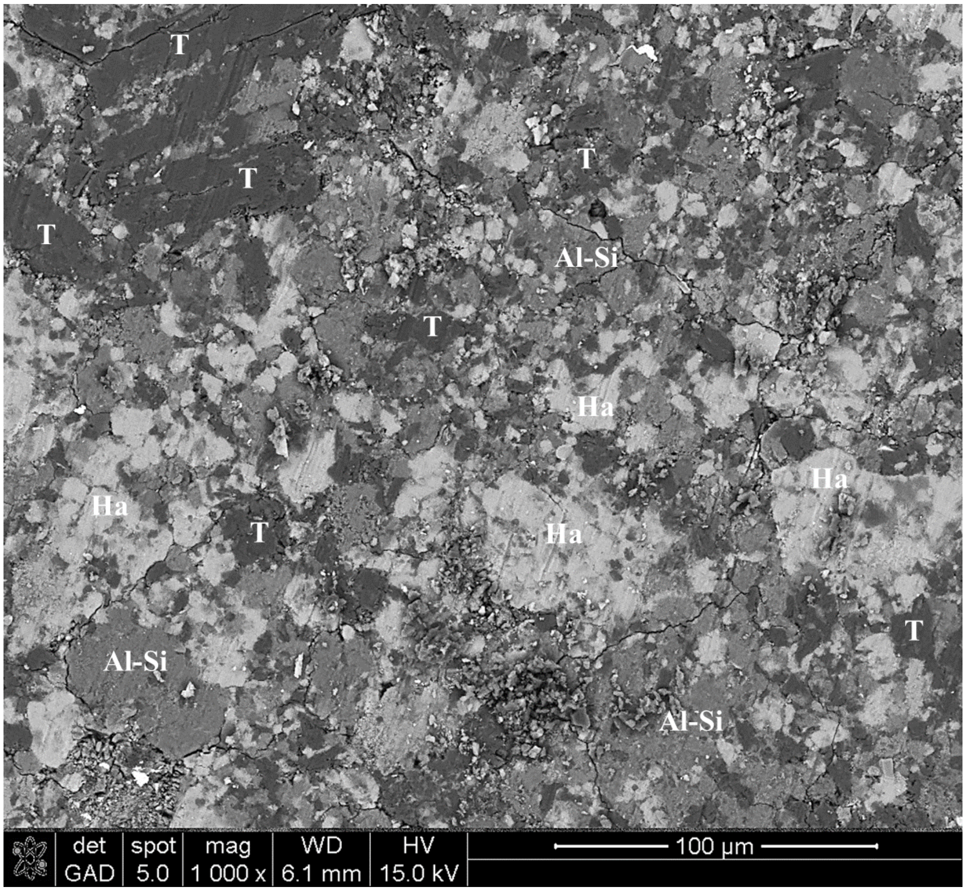



Figure 137. SEM photomicrograph in BSE mode of sample TEX-01 (pressed pellet) with identification of likely mineral phases based on EDS analysis (T: trona; Ha: halite; Al-Si: alumino-silicates).

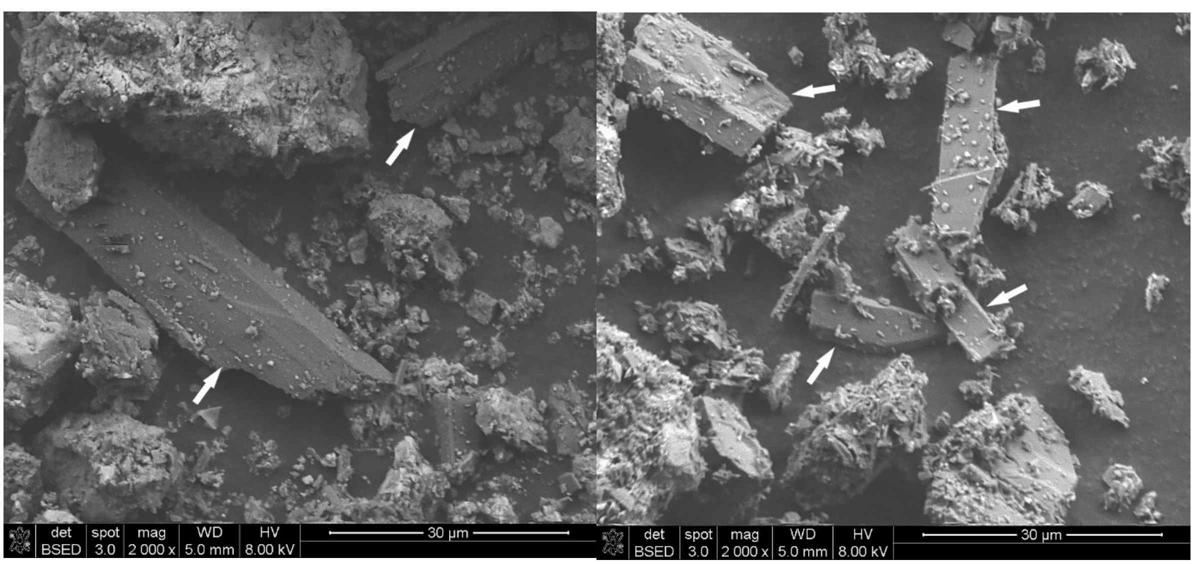



Figure 138. SEM photomicrocraphs of samples MRK-01 (left) and TLX-01 (right) showing the columnar and prismatic morphology of trona crystals (marked by the arrows).

The information obtained from the analyses of possible alkali sources for glassmaking helps in the interpretation of the chemical composition of the archaeological glass samples which is the topic of the next chapter.

# 9. CHARACTERIZATION OF ARCHAEOLOGICAL GLASS

To understand colonial glass production in Mexico we can rely on three main lines of evidence: historical descriptions of glass production; analysis of the chemical composition of archaeological glass; and chemical analyses of raw materials. Although it is possible to learn a lot about glass production from historical documents, as shown in Chapter 6, and typological approaches such as the one presented in Chapter 7 are not only useful but necessary for the interpretation of an assemblage, these two lines of evidence do not provide the information needed to explore the transfer of glass technology to the Americas and its adaptation to the local resources. For this reason, the chemical composition of a selection of artifacts was determined by a multi-analytical approach that included SEM-EDS, EPMA and LA-ICP-MS. This methodology allowed to obtain compositional profiles based on major, minor, and trace elements as well as REEs, providing thus information on raw material selection and technological adaptation. The sample set is composed of 105 glass artifacts from Mexico City, with a particular focus on production waste, and 28 from Puebla. In addition, 38 glass artifacts from Catalonia, which included 23 from Barcelona and 15 from Sant Bartomeu del Grau (Vic), were also sampled and analyzed for comparanda.

## 9.1. Glass Chemical Composition

The seminal studies on the composition of ancient glass performed by Turner (1956) and shortly after by Sayre and Smith (1961) showed that different types of glasses were made in Antiquity and that their compositions could be related to the area where they came from. The main types that they identified, which included: high magnesia glass (plant ash glass), low magnesia glass (natron), and high lead glass, not only remain relevant (Henderson 2013:83) but also set the foundations for the identification of the technological traditions developed through time, and the creation of extensive scholarship on archaeological glass from different regions.

The combination of the main glassmaking raw materials: silica, a source of alkali, and a stabilizer (as part of the raw materials or deliberately added), plus additives like colorants, decolorizers, opacifiers, or cullet, leads to compositional profiles based on major, minor, and trace elements whose examination can provide clues on technological choices made by the glassmakers such as the type and source of raw materials used, or practices like recycling. As the body of data on glass composition from different areas and time periods grew, it has become possible to investigate the existence of primary and secondary glass production centers,[255] the provenance of glass, and the movement of glass objects and glass technology through time and space (Henderson 2013:84-85). Here, the study of glass composition of archaeological glass recovered in Mexico City and Puebla makes it possible to examine the raw materials used to make glass in New Spain, to evaluate the extent to which it followed the Iberian tradition, and to identify adaptations, influences, and innovations.

### 9.1.1. Comparison of major and minor elements in glass measured with EPMA-WDS and LA-ICP-MS

SEM-EDS analysis was first used for a qualitative screening of the samples' chemical composition and to observe their microstructure. Following this preliminary investigation, elements were selected to be probed with EPMA-WDS, which in turn, also provided the Si values needed for the calibration of the LA-ICP-MS.

[255] Primary glass production centers prepare raw glass in large quantities which is then distributed to secondary centers where it is worked into objects (Freestone 2005: 196-197).

As mentioned in Chapter 4, EPMA-WDS (hereafter shortened to WDS) was conducted in two locations: the samples of Spanish glass were analyzed at CCiTUB (Universitat de Barcelona), and the Mexican glass samples at UCLA, so it was important to also assess the consistency between the data from both sites. For the major and minor elements under consideration, the correlation between WDS and LA-ICP-MS data for the various elements, and over a large compositional range, is linear and excellent as shown by the coefficients of determination almost always higher than 0.99. Moreover, the UCLA and CCiTUB WDS data are homogeneous and consistent, and well-integrated along the regression lines (Figure 139). For Al, K, and Ti, the slope of the regression is close to the theoretical value of one, while for the other elements the divergence is more pronounced. Sodium and calcium concentrations are generally higher with LA-ICP-MS while for magnesium and iron they are lower. Sodium and magnesium data are also more scattered, especially for the higher concentrations, a pattern which is probably linked to their lower atomic number (Z). For consistency with the analysis of the trace elements and REE's, the results, interpretations, and discussions that follow are based on the compositional data obtained with LA-ICP-MS.

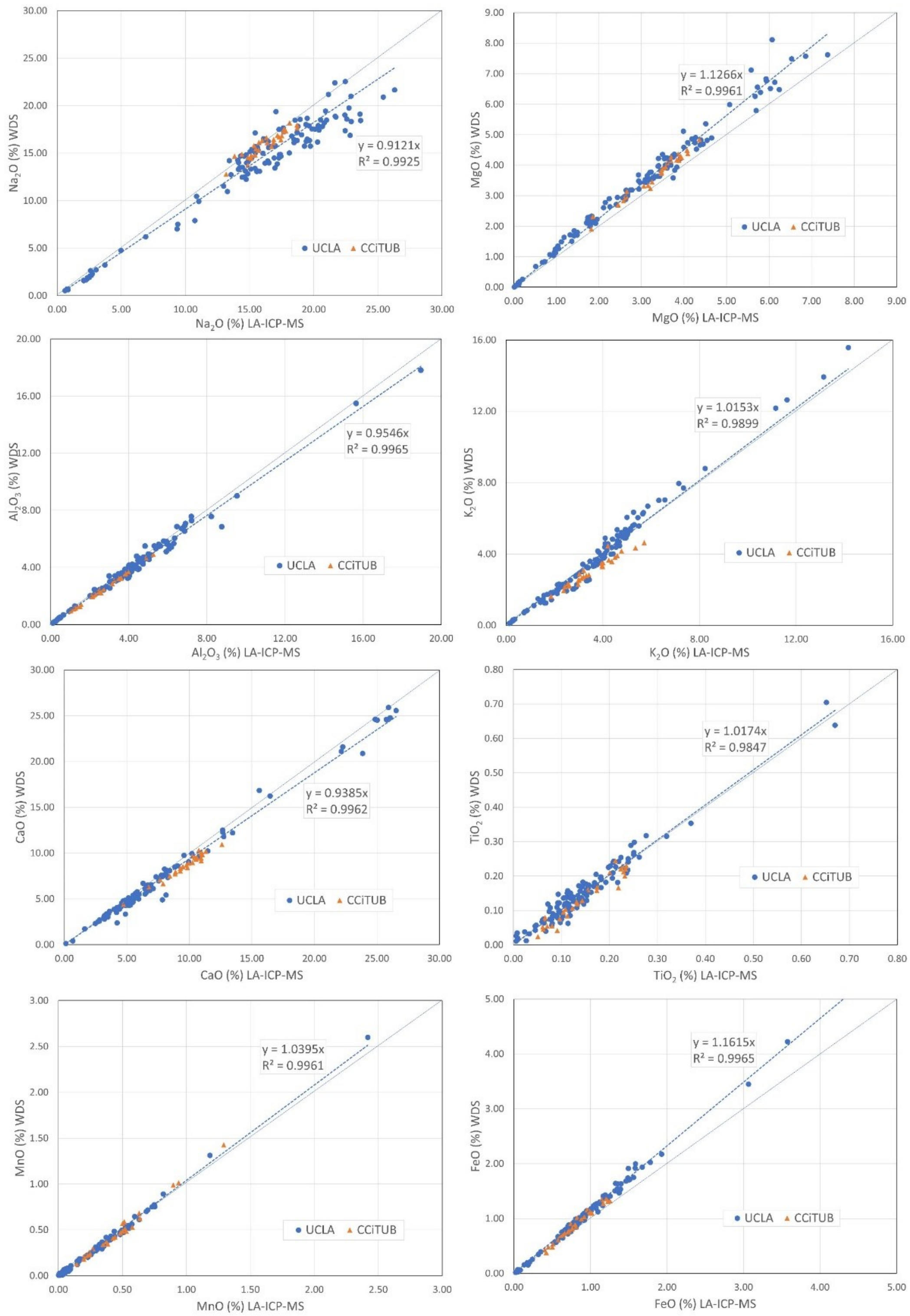



Figure 139. Correlations between WDS and LA-ICP-MS analysis of major and minor elements for the glass samples collected in Mexico and Spain.

### 9.1.2 Chemical composition of Archaeological Glass from Mexico and Spain

The results of the analyses of the chemical composition of the archaeological glass samples analyzed (Appendix 1) are discussed below in terms of raw materials. The full compositional data can be consulted in Appendix 2.

#### 9.1.2.1. The glass former: silica

As a network former, silica is the main component of glass and usually introduced in the form of sand. If the latter is very pure and consists mainly of quartz, the level of impurities will be extremely low. More often, the sand contains other mineral phases which will introduce additional elements in the glass composition, particularly aluminum as many minerals are alumino-silicates. In Figure 140, the bivariate plot of Si and Al (expressed in oxides), highlights the negative trend between these two elements and shows that more than half of the samples from Mexico City and Puebla have relatively high levels of alumina, above 4%, whereas the majority of samples from Catalonia are below. The results for the latter are consistent with studies on Old World glass from different periods which have shown that alumina levels tend to be, on average, lower than 4% (Henderson 2013:237, 241, 244-245, 283, 287, 293). On the other hand, in Mexico, large proportion of the glass production used relatively impure sands as raw material reflected in the higher alumina levels. There is also a small group of samples from glass vessels recovered in both Mexico City and Puebla with high silica and very low alumina (<0.5%), indicating the use of a relatively pure source of silica, such as crushed quartz pebbles. Although such deposits may contain elements associated with clay minerals that may find their way into the glass, very few elements can be incorporated into the crystal structure of quartz and only at trace levels, so that this type of raw material contributes mainly silica to the composition of the glass (Degryse and Shortland 2020:121).

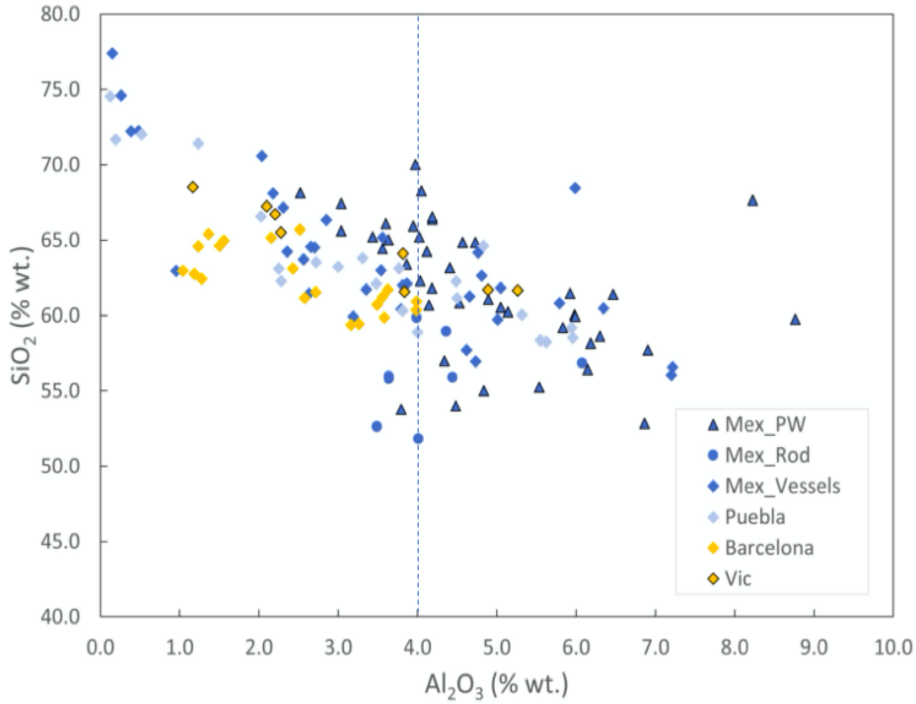



Figure 140. A biplot of $SiO_2$ against $Al_2O_3$ present in glass samples from Mexico and Catalonia.

Beside aluminum, other elements, notably REEs which are mainly concentrated in the clay and silt fraction, can be used to distinguish sand raw materials from different geological sources. Neodymium (Nd) in particular, enters into the glass from the non-quartz mineral content of the silica raw material used. Its levels do not change significantly with the addition of colorants or opacifiers, nor is it affected by recycling practices, and therefore it has a great potential in tracing the origins of the silica (Degryse and Shortland 2020:122). When Nd is plot against alumina (Figure 141), the data shows a clear separation between the samples from Spain and those from Mexico, with distinctive relationships, effectively indicating the use of different sand sources.

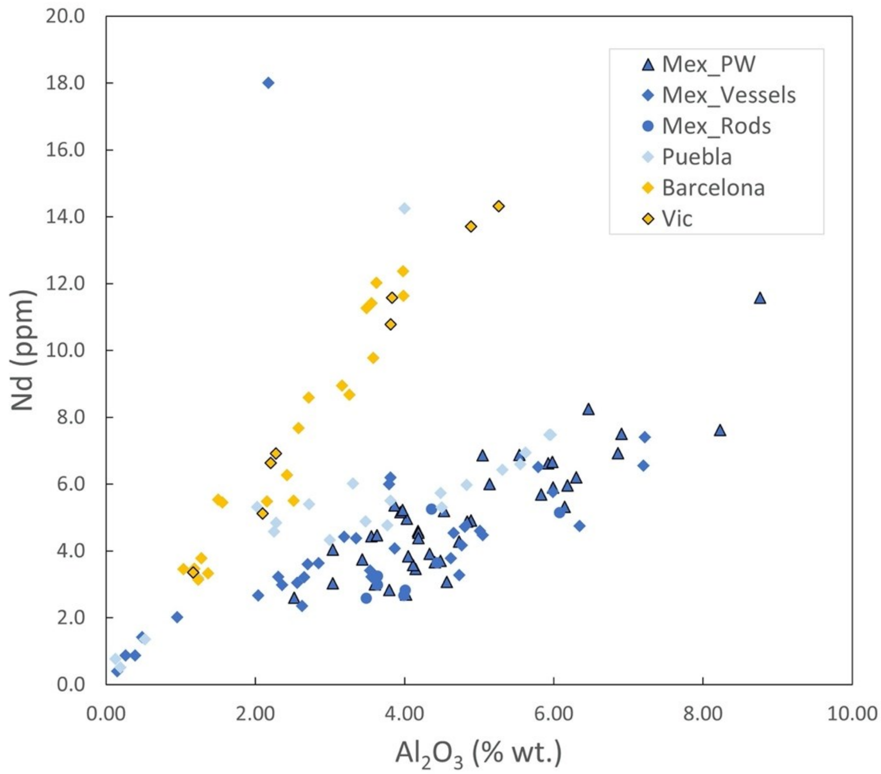



Figure 141. A biplot of Nd against $Al_2O_3$ in the glass samples from Mexico and Catalonia.

9.1.2.2 Nature and source of the alkalis and calcium

Since the studies done in the 1960s (Sayre and Smith 1961), it was determined that early soda-lime-silica glasses could be divided into two types which corresponded to the raw materials used to make them: one with relatively high magnesia and high potash (more than 1.5% of each oxide) which was made using plant ash as a flux; and another one with low magnesia and low potash content (less than 1.5% of each oxide) made with natron as the alkali (Degryse and Shortland 2020:118-119; Freestone 2005:196; Henderson 2013:85, 92). In between these two main groups there is sometimes a third group with intermediate values that has been interpreted as glass of mixed alkali, meaning that the two types of fluxing agents, plant ash and natron, were used (Henderson 2013:100).

In order to identify the type of alkali used in New Spain, and to see if the archaeological material reflects the information from historical sources, the relation between sodium, magnesium, potassium, and calcium was investigated. In a ternary diagram showing the relative proportions of CaO, $Na_2O$ and ($MgO+K_2O$) in the glass from Mexico City and Puebla (Figure 143), it can be observed that for most samples from Mexico City, including all the production waste, the relative proportions of ($MgO+K_2O$) are between 12 and 37%, a clear indicator of the use of plant ash as the alkali source. Only two samples from glass vessels show high Na and low ($MgO+K_2O$) levels pointing to the use of an evaporite-based alkali source like *tequesquite*. The paucity of glass samples with low ($MgO+K_2O$) and high NaO also reveals that *tequesquite* was not a frequent source of alkali for glassmaking. There is also a clear group containing most samples from Puebla that clusters in between the *tequesquite* and plant ash groups. This group can be interpreted in two ways: 1) it could either represent glass made using ashes from a different plant species that contains higher Na and lower amounts of Mg and K; or 2) correspond to mixed alkali glass in which both plant ash and *tequesquite* were used as fluxing agents. In addition, there is a small cluster of samples with very low levels of sodium and higher magnesium + potassium, typical of potash glass which is made with ashes from non-halophytic plants such as ferns or certain types of wood. Interestingly, all samples in this group are colorless except one that is aquamarine, and it also includes the rim of a thin-walled colorless bowl decorated with engraved linear designs (Figure 142).


Figure 142. Glass artifacts found in Mexico City made with very pure sand (photos: Karime Castillo).

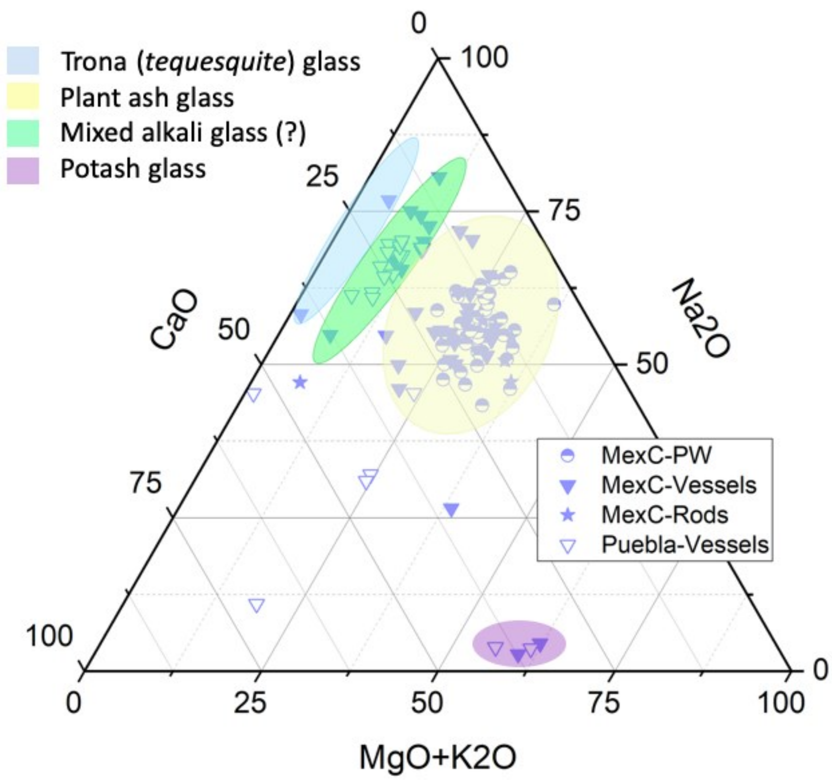



Figure 143. Ternary diagram of $Na_2O$ – $MgO + K_2O$ – $CaO$ showing the main glass groups in Mexico according to the fluxing agent used.

Considering that the majority of the Mexican glass samples have a relatively high amount of sodium and show levels of magnesium and potassium expected in a plant ash glass based on studies of glass from Europe (Gratuze and Janssens 2004:672), it seems that in New Spain the preferred alkali source was halophyte plant ash such as *barrilla*. This means that colonial glassmakers were following the Iberian tradition even though *tequesquite* is mentioned as a recurrent expense in the records of eighteenth-century glass furnaces. As for the group of possible mixed alkali located between the plant ash and the '*tequesquite'* glass, reports from a glassmaker at the Casa del Apartado mention that *tequesquite* was sometimes added to the glass melt when a harvest of plant ash was not producing glass of sufficient quality,[256] so it is possible that the samples in this group represent such an adaptation. We must also remember that Aperechea recommended the rental of additional lands to cultivate *barrilla* considering the constant floods that sometimes wasted the harvest,[257] which means glassmakers used plants growing in different areas. It is interesting to note that most of the samples from Puebla fall within this potential mixed alkali glass group.

When the glass samples from Spain are included into the ternary diagram (Figure 144), the use of plant ash as flux in both Spain and New Spain becomes more evident, yet the slight offset of the Spain samples cluster, due primarily to the presence of some more calcium, indicates the use of a different type of plant ashes. Those used in Spain seem to have a lower content of MgO and $K_2O$ than the ones used in Mexico City. The diagram in Figure 144 also displays samples labeled as "imported," the majority of which are extremely high in CaO and very low in $Na_2O$. They clearly constitute a different group of Ca-rich glass and correspond

[256] AGN, Indiferente Virreinal, caja 5231, exp. 32, fs. 6-7.
[257] AGN, Casa de Moneda, vol. 46, exp. 20, fs.1-3.

mostly to dark green wine bottles including one embossed with the text "Bristol Glassworks." The sample from Puebla that falls within this Ca-rich group also comes from a dark green fragment which probably belonged to an imported bottle like the other samples in this group.

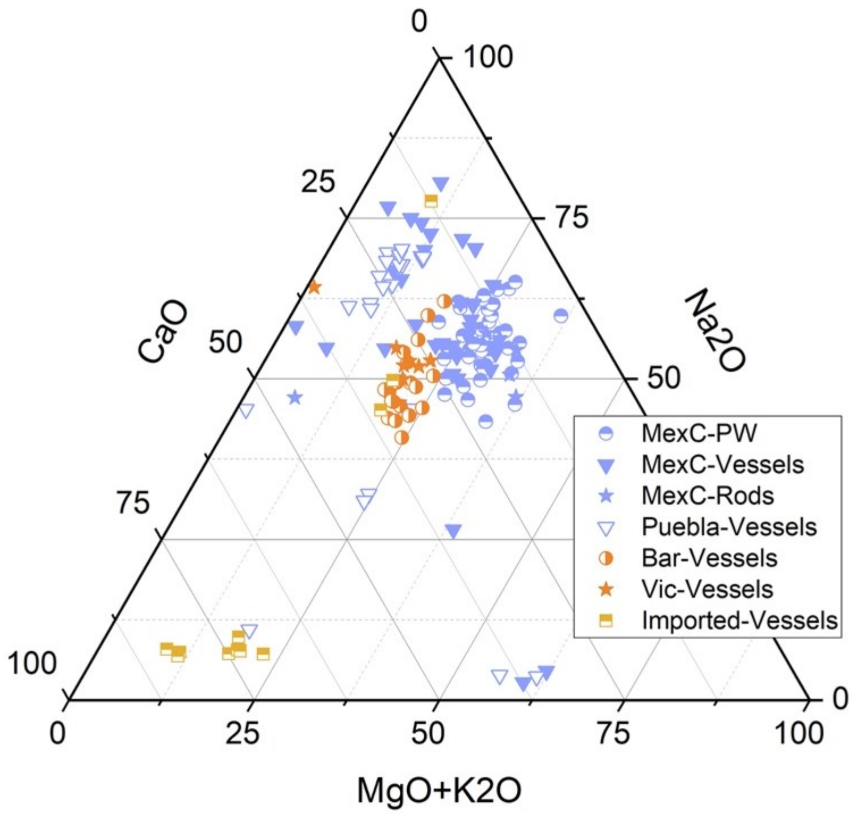



Figure 144. Ternary diagram of CaO – MgO + $K_2O$ – $Na_2O$ showing the samples from Mexico, Spain, and those identified as imported according to the fluxing agent used.

9.1.2.3 Colorants and decolorizers

The archaeological glass artifacts are colored in a wide range of hues, tints, and shades, or are simply colorless. The chemical composition of the glass samples can also provide some clues regarding colorants and other additives. Most colorless glass from both Mexico and Spain contains significant amounts of manganese which was most likely added as a decolorizer, although some of this Mn might also come from the plant ash. There are two samples, one from

Catalonia (SBG-20b) and one from Mexico City (B16-25) with high levels of antimony (Sb > 1800 ppm) that may represent Sb-decolorized glass (Figure 145).


Figure 145. Colorless glass from Mexico City (left) and Sant Bartomeu del Grau (right) decolorized with Sb (photos: Karime Castillo).

As mentioned in Chapter 8, manganese can also act as a colorant when present in amounts above 0.8 %. A set of glass rods from Mexico City (B16-41) and a vial from Puebla are two examples where Mn was used to obtain a dark purple glass (Figure 146).

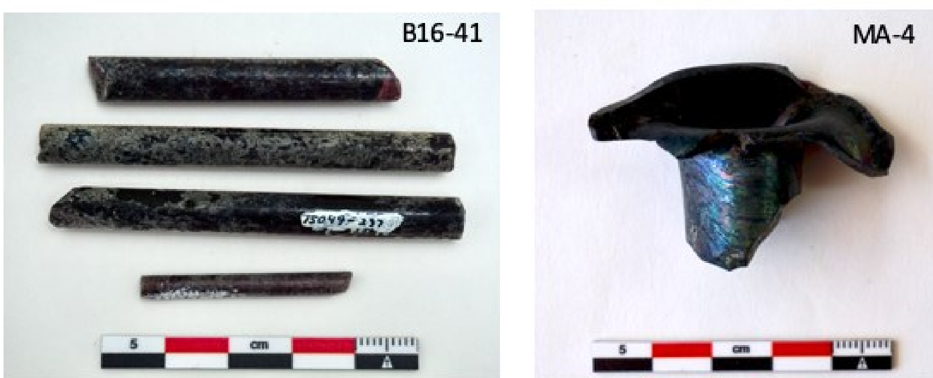



Figure 146. Purple glass artifacts from Mexico colorized with manganese (photos: Karime Castillo).

Based on the compositional data, blue glass was obtained through the addition of copper or cobalt knowing that a few hundred parts per million of cobalt can impart a deep blue color to the glass (Cholakova et al. 2017:123). There are only a few samples containing cobalt in significant amounts, notably two glass artifacts from Mexico City, J70-19 and B16-56, which owe their deep blue color to the presence of this element (Figure 147). Where cobalt is absent, copper of the order of 1% or less produces a pale blue color (Biek and Bayley 1979:8).

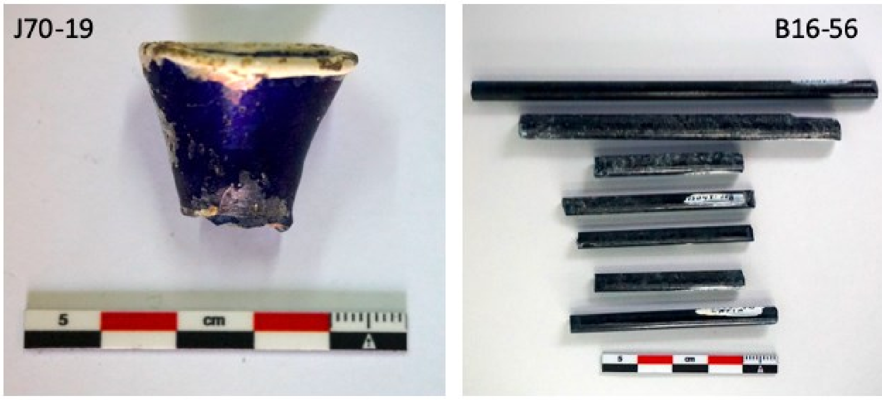



Figure 147. Blue glass from Mexico City colored with cobalt (photos: Karime Castillo).

Many samples from Catalonia and Mexico have a blue color resulting from the presence of copper. A few examples from Mexico City with copper oxide levels above 1 % (B16-53, 1.76%; J70-20, 1.96%; ApNi-13,1.65%; and TM-38, 2.63%) are shown in Figure 148.

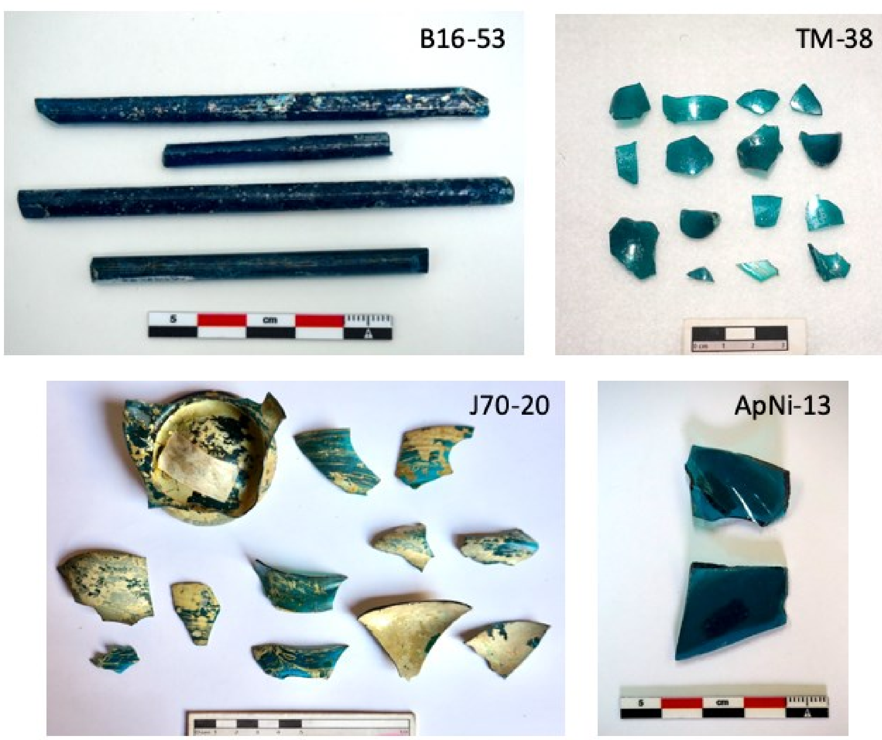
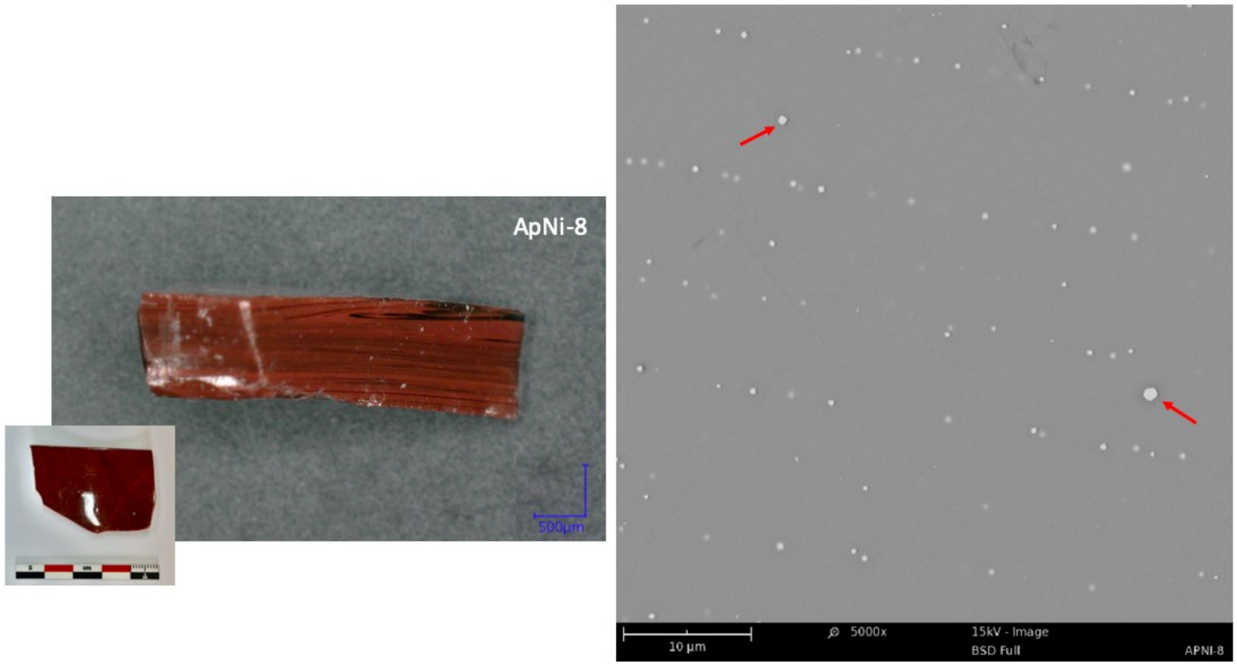



Figure 148. Blue glass from Mexico City colored with copper (photos: Karime Castillo).

In most of the green samples the color is related to iron oxide with concentrations around 1.5% and higher. However, there are some rods, for which the green color results from the addition of copper (Figure 149).


Figure 149. Green glass rods from Mexico City colored with copper (photos: Karime Castillo).

In the collections analyzed, there is also an example of opaque dark red and black glass that swirl around the object forming linear patterns, which are more evident when observed in cross-section at high magnification (Figure 150a). After examination with SEM, it becomes apparent that the red color is produced by the presence of copper nanoparticles which are arranged in parallel lines that follow the patterns visible on the glass. Similar to the findings made by Drünert and other researchers (Drünert et al. 2018:378), the sample shows two kinds of copper particles: occasional larger spheres larger than 1μm scattered randomly, and smaller crystallites arranged along striae throughout the sample (Figure 150b).




a b

Figure 150. Opaque dark red glass recovered in Mexico City: a) Cross-section showing the streaks of red and black (dark green) glass (magnification: 50x); b) SEM micrograph of the opaque dark red glass showing the linear arrangement of the copper crystallites and the larger copper particles (red arrows) responsible for the red color.

The use of opacifiers was also investigated in one sample taken from a fragmented Venetian wine glass decorated with *lattimo* glass in a *vetro a fili* pattern (Figure 151, left), and in one from a Catalan fragment of a glass *à la façon de Venise* decorated with white enamel (Figure 151, right). An examination at high magnification shows that in the Venetian example the *lattimo* canes are embedded within the colorless glass (Figure 152).


Figure 151. Venetian wine glass fragment decorated with *lattimo* in a *vetro a fili* pattern (left) (photo: Karime Castillo), and Catalan glass *à la façon de Venise* with white enamel imitating *vetro a fili* (right) (photo: Trinitat Pradell).

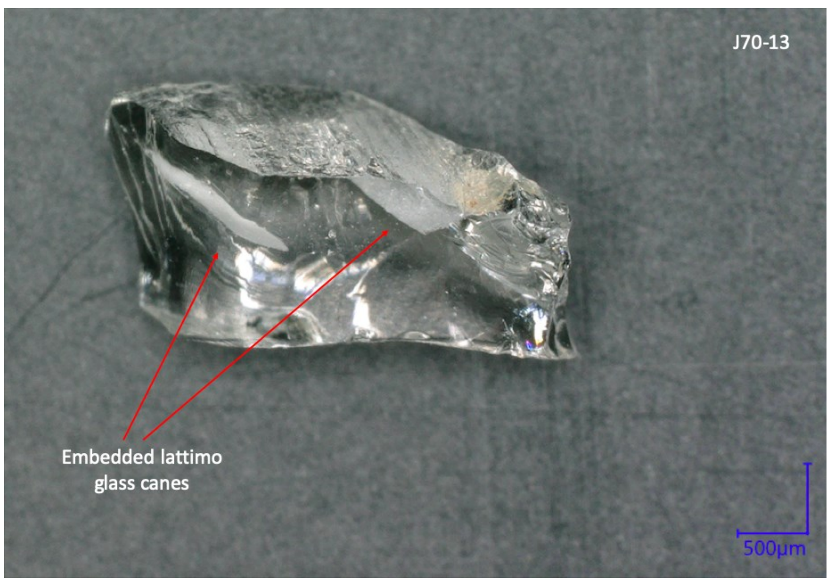



Figure 152. Sample of Venetian glass fragment with embedded *lattimo* canes (magnification: 50x).

In both the *lattimo* canes in the Venetian sample (Figure 153) and the white enamel in the Catalan sample of glass *à la façon de Venise*, the white glass and enamel were obtained through the use of tin (Sn), of which the particles scatter the light, creating the effect of an opaque white glass. While the enamel in the Catalan sample is partially embedded into the glass (Figure 154), a significant portion of the enamel remained on the glass surface, which is the reason why part of the decoration was lost. In should also be noted that in both cases the *lattimo* and the white enamel are Pb-rich glasses, hence their brighter appearance on the BSE micrographs.

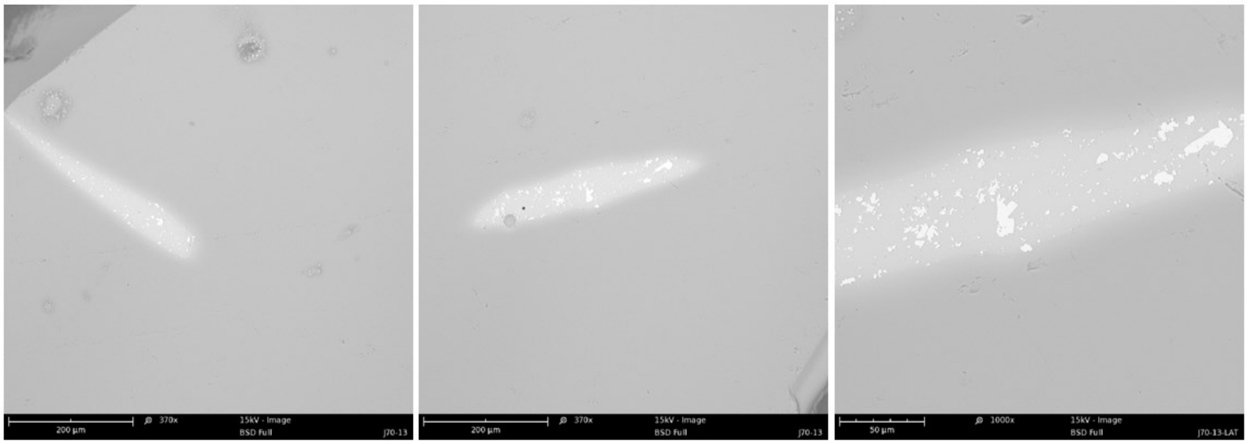


Figure 153. BSE micrographs showing the embedded *lattimo* cane in the Venetian glass sample. The tin-rich particles, showing brighter, can be seen dispersed within the *lattimo* cane.

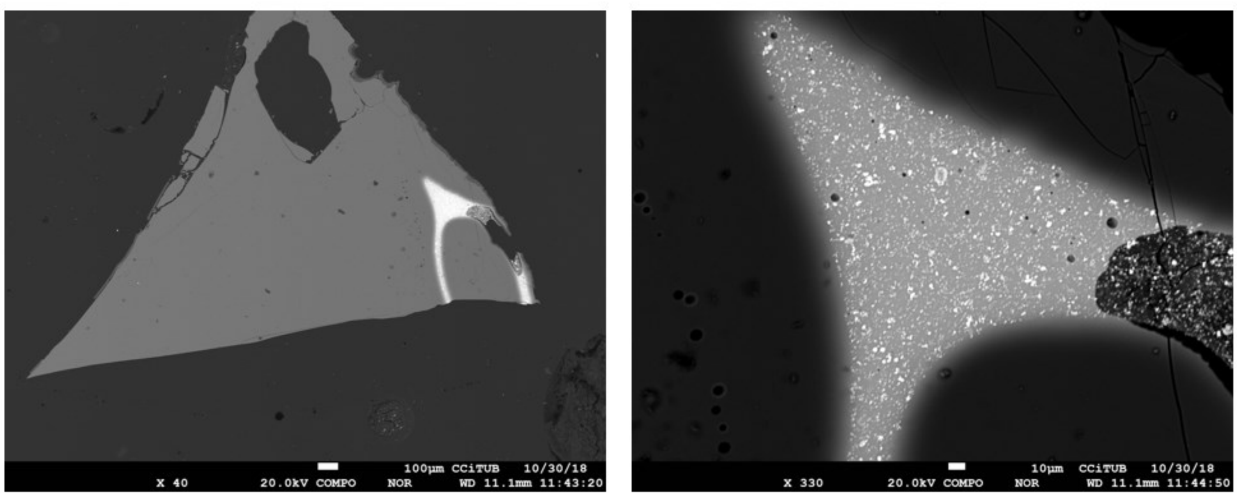



Figure 154. BSE micrograph of a sample of Catalan glass *à la façon de Venise* showing the white enamel partially embedded into the glass (left), and the Sn particles dispersed within the enamel (right).

### 9.2.1. The Transfer of Glass Technology to the Americas: Adaptation and Technological Choices

The analysis of the chemical composition of the archaeological glass samples from Mexico City and Catalonia, in conjunction with the information retrieved from the historical records permits a better understanding of the process of transfer of glass technology from Europe to the Americas. The historical records strongly suggest that glassmakers in New Spain were making glass *ab initio* using local raw materials. This was confirmed by the chemical analysis of the Mexican glass samples. In general, the sand sources used for glassmaking in Catalonia were purer than the sand sources used in New Spain as shown by the relation between the amounts of silica and alumina as well as minor elements and REEs such as neodymium.

An important enigma to solve was the type of alkali used in colonial Mexico, especially because the historical sources mentioned the presence of two different types of fluxing agents present in the glass workshops: *barrilla* plant ash and *tequesquite*. The analyses revealed that in New Spain, glassmakers followed the Iberian tradition of glassmaking based on the use of plant ash as a flux. However, colonial glass artisans had to adapt to the resources available in the new land. After an initial period during which glassmakers probably experimented with different halophyte plants, they figured out that those growing in Michoacán and Xaltocan provided the best results. The great importance of this resource in colonial glassmaking is evident in the restrictions emitted by colonial authorities regarding the collection of *barrilla* plants by people other than those involved in gold parting or glassmaking, as well as its collection before it fully matured. The adaptations did not end there. Heavy rains and the consequent floods would sometimes ruin the *barrilla* harvest, causing glassmakers to struggle producing glass of acceptable quality. When this happened, these artisans turned to another local resource, *tequesquite*, which when added to a faulty glass batch was sometimes able to make it workable. The analyses of Mexican samples, however, show that very few samples fall within the levels of $Na_2O$, $MgO + K_2O$, and $CaO$ where a glass made using an evaporite source as the fluxing agent would fall, meaning that *tequesquite* was not the preferred source of alkali. Yet, this raw material was crucial for the colonial glass industry given its potential to save a glass batch when *barrilla* failed. It is also possible that *tequesquite* was used in combination with *barrilla* to produce mixed alkali glass, considering the group that falls in between the expected values of evaportie glasses and that of halophyte plant ash. This possibility is particularly intriguing considering that the majority of the glass samples from Puebla fall within this group. However, the intermediate group may also represent the use of a different *barrilla* plant. More research on potential halophyte plants used for colonial glassmaking is needed to answer this question. Regardless, the analyses suggest that glassmakers in Mexico City and Puebla could have been using different raw materials. Moreover, the collection of glass from Puebla did not include production waste and was considerably smaller than the one from Mexico City, and the historical records of Puebla consulted so far do not provide the rich amount of technological information available in those from Mexico City, so these questions remain open. Further analyses of archaeological glass from Puebla is needed to better understand the technology of Pueblan glass and to determine if the glass made in these major colonial cities and glass production centers can be firmly distinguished from one another.

# 10. NEW SPANISH GLASS IN LOCAL AND GLOBAL CONTEXT

Having explored the transfer of glass technology to the New World, this concluding chapter has two aims: 1) to explore the impact that this transfer had in the Americas but also in the technology and the perception of this material by the Europeans themselves; and 2) to place colonial glassmaking in the global context of its time. For the first objective, I present a discussion on the selective adoption, adaptation, and use of glass by local communities, followed by an exploration of the new meaning that mundane materials like glass may have acquired for Europeans. The second part will show that the development of glass technology and the products made were also always influenced by the global movement of people and things made possible by the explosion in transoceanic travel that began in the late fifteenth century.

## 10.1. Glass in New Spanish Society: Adoption, Use, and Value

Glass and glassmaking represent just one example of the many other European, and soon after also Asian and African, materials and technologies that forever changed material culture in the New World. At the same time, the material culture, technologies, and resources available in the Americas also promoted changes to the incoming ones. Both locals and newcomers confronted a material word and ways of life completely different to their own and each one made choices along the way in terms of what was adopted, how it was valued, and how it was used. All of them exercised agency in their use of material culture to interact with each other.

As mentioned in Chapter 6, the first glass objects to arrive in the New World were glass beads and a few other glass articles brought by the crew. Beads in particular figure prominently in the first encounters between newcomers and local communities as part of the exchanges known as *rescate*,[258] in which objects of low value by European standards, were exchanged for local goods. Glass beads, used for adornment by Europeans and people in the Americas alike (Martins Torres 2020:3), acquired a variety of new meanings, uses, and values in the Contact period. For the Spaniards arriving in the New World, these small objects represented a way to make peaceful contact and initiate interactions with the local inhabitants, as well as a medium of barter to obtain food and other goods. For indigenous people, glass beads represented a familiar object made in an unusual material displaying colors and designs unlike anything they had seen before and they were soon incorporated into their trade networks (Deagan 1987:156-157). The demand for glass beads in the New World became so high that in a single year up to three million beads could arrive in the Spanish galleons (Deagan 2002:120). As discussed in Chapter 5, beads of materials considered precious, such as jade, rock crystal, and amber, had been made, exchanged, and placed in offerings, and offered as tribute in Mesoamerica for millennia, so the immediate acceptance of glass beads, which shared the shine, translucency, and reflective qualities of local precious materials should not be surprising.

During the initial exchanges between Spaniards and the local communities, glass beads were perceived through two radically different value systems: one European, and a very dissimilar indigenous one. As a social construct, the concept of value is defined by the cultural context in which it is created (Papadopoulos and Urton 2012:1). This means that what is considered valuable can significantly vary from one culture to another, although there are certain characteristics that can confer a special value to certain objects and materials such as rarity or scarcity, appearance, durability, difficulty of procurement, usefulness, restricted access,

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[258] An analysis on these exchanges has recently been proposed by Martins Torres (2019a: 159-189), in which she effectively demonstrates indigenous agency in this practice as well as the strong influence this groups exerted on bead production by demanding beads of particular colors.

specialized manufacturing skills or technology, as well as the time need for their processing (Berdan 1992:293). Although Spaniards considered glass beads mundane objects of lesser value,[259] they were novelties in the New World. At the time of contact, glass beads could only be acquired from the newly arrived Europeans, this made glass beads not only rare and difficult to procure, but their making also required specialized manufacturing skills unknown in the Americas. Moreover, beads of glass-like materials were already part of prestige goods in many parts of Mesoamerica, and glass beads came to enrich the already existing repertoire. Given that glass beads also displayed desirable optical qualities in terms of their colors, translucency, and shine, their integration and adoption was probably straightforward. The preference for particular colors also responded to the symbolic system already in place. In the case of Mesoamerica, it should not be surprising that preferred bead colors included green and blue (Martins Torres 2019a:183), considering the strong symbolic meaning of these colors in Mesoamerican cosmovision, as discussed in Chapter 5. Glass beads became incorporated into indigenous practices, including the making of protective charms, certain healing practices, and funerary rituals (Blair 2015; Konwest et al. 2020; López Alonso et al. 2002:58); they also became highly successful barter items amongst indigenous populations during the Contact period and for many indigenous groups their importance prevailed throughout the Colonial era (Deagan 1987:156-157).

Another point worth emphasizing, is the variety of roles glass beads played in the mediation of social relationships, especially during the period of contact. As mentioned above, glass beads were often used by Europeans to initiate peaceful contact with indigenous

[259] Martins Torres (2019a: 129, 152-153, 158) points out that glass beads were used to adorn elite clothing and to make jewelry, showing that beads were used by elites and non-elite groups alike, and that these objects had the potential to add value to goods such as clothing.

communities and were offered by Hernan Cortés in his first encounter with the Mexica lord Moctezuma (Cortés 1993 [1519]:209). In such cases, it could be said that glass beads were playing a sort of diplomatic role, and they were meant to establish peaceful interactions and establish alliances. Beads were also used to facilitate trade, and in some cases, these small objects became instruments of survival for Spaniards in distress, so even when beads had little economic value for Europeans, in the context of explorations in the New World they could become their most valuable possession as happened to those Spaniards participating in the failed expedition of Hernán Cortés (1993 [1525]) to Las Hibueras, or to Alvar Nuñez Cabeza de Vaca (1984 [1542]) when he found himself alone after the shipwreck of the Narvaez expedition to Florida. In both cases, having glass beads to offer the indigenous people allowed them to obtain help from them when they were at their weakest, saving their lives. Glass beads also acquired specific roles in indigenous communities. They rapidly became part of their prestige goods and soon were incorporated into indigenous trade networks in which their value was dictated not by European standards, but by those of the communities who traded them. Novel colors and color combinations unavailable in natural materials may have acquired particular meanings; their display on articles of clothing or personal adornment probably conveyed information regarding the status and identity of the wearer; and their placement in graves as funerary offerings or part of the adornment of the deceased is indicative of the value attributed to them by indigenous communities.

The early *rescate* exchanges were not the only time in the Colonial period that glass was used in the context of trade. While silver coinage, the *real*, was the official form of currency in New Spain, the lowest value minted was half a *real*, which was unaffordable for a significant part of the population. This motivated the emergence of a non-official currency of lower value, tolerated by the authorities, emitted by small businesses known as *tlacos* (1/8 *real*) and *pilones* (1/16 *real*). These were chips made of wood, metal, glass, ceramic, leather, bone, rubber, or soap marked and used for small everyday purchases until 1767, when viceregal authorities authorized the mint to produce copper coinage in addition to silver *reales* (Beltrán Martínez 1952:379; González Gutiérrez 1995:65; Muñoz 1968:61). Although the mention and imposition of glass as an unofficial currency of lower value reflected European ideas, it did not necessarily preclude higher worth in indigenous value systems. The continued use of crystals in healing practices by indigenous communities (Aguirre Beltrán 1992; Brady and Prufer 1999) supports that different value systems coexisted.

Beside glass beads, there are other examples of glass objects used by indigenous people. One is narrated by an English traveler, John Chilton (1926 [1572]:22-23) who embarked for the Americas in 1568, only to find himself imprisoned by a Huastec community four years later after falling sick and getting lost, while exploring the area of the Pánuco River. He was told by his captors that he would be killed and eaten, but his life was spared because he was emaciated and they feared that he might suffer from smallpox. Grateful, he offered his wine to the Huastec lords, a product they greatly valued, and requested water. To his astonishment, it was brought to him in a Venetian glass with a golden rim, and was told by his captors that they found the glass in Jalapa after they burned down an Augustinian convent. While Chilton's story is rather unique, glass objects such as the one described, must have at least inspired curiosity in indigenous people. Presenting it to a foreign prisoner, may have been a display of power and intimidation, or a gesture of gratitude for the wine received. Regardless, the presence of a Venetian glass in an indigenous community far away from the main Spanish cities is noteworthy.

A particularly interesting form of appropriation of glass by indigenous communities was documented in Cuba (Febles and Domínguez 1987), where sherds of glass bottles from the eighteenth and nineteenth centuries were worked into tools through knapping. This practice has also been reported in several sites in the USA dating from the seventeenth to the nineteenth centuries (e.g., Clark 1981; McCary 1962; Wilkie 1996) but it has not yet been reported for colonial Mexico. However, obsidian sources continued to be exploited and the material circulated through indigenous exchange networks at least until the mid-seventeenth century (Forde 2017; Pastrana and Fournier 1998; Rodríguez-Alegría 2008), as mentioned in Chapter 5, so glass knapping may not have appeared until later. The practice of working industrial glass was documented in the Maya highlands by Hayden and Nelson (1981:893-896) in the 1970s. While the authors consider this practice a continuity with the lithic tradition of the area, it remains unclear when glass began to be worked in that way.

In the early years of the Colonial period, when the first glass workshops were established in New Spain, glass articles were probably not abundant and may have been difficult to find. At the same time, there was no shortage of locally made ceramic cooking-ware and serving tableware of excellent quality to cover the needs of indigenous communities and Spaniards alike. Research by Rodríguez Alegría (2005a; 2016:51), for instance, has shown ample use and consumption of indigenous ceramics by Europeans living in Mexico City regardless of their wealth. But glass was certainly present in many households. In his description of a sixteenth-century house based on inventories from the *Real Fisco de la Inquisición*, Toussaint (1939:28) mentions that while most of the crockery would be "from the land," porcelain cups and glass dishes would be part of the fine tableware of a household. It is thus possible that fine glass tableware was used to display wealth or refinement in a similar way as porcelain. In colonial

Mexico, where material culture played a paramount role in the mediation of social relationships, the display of luxury goods publicly represented the elite and those who aspired to become part of it (Rubial García 2002:72-73; Zárate Toscano 2005:325).

Glass of different qualities was made in New Spain and, according to the inventories of Doña Micaela's workshop,[260] different raw materials were selected to make fine glass. The mention of glass objects in dowries indicates that they were deemed valuable enough to be included (Castillo Cárdenas 2007:127-128). Dowry inventories are not specific on the type of glass, but they probably referred to the one of fine quality. In terms of price, glass objects were sometimes more expensive than porcelain but never reached the high prices of silver. For instance, in the eighteenth century the price for a silver cruet was 22 *pesos*,[261] for a glass or crystal cruet, 1 *peso*,[262] and for a Chinese porcelain cruet, 4 *reales*.[263] The finest glass was considered to be that imported from Europe and it was worthy of display. For example, in the Royal Houses of Chapultepec in Mexico City, where the viceroy, the Marquis of Villena lived in the 1640s, Venetian glass was displayed in a sideboard (Curiel 2002:33).

Flat glass for windows, wall mirrors, and sideboards was also expensive. Not everybody could afford the luxury of having glass windows, especially at the beginning of the colonial period, when even the Cathedral in Mexico City had painted waxed canvases with depictions of Saints instead of glass windows at least until 1588 (Toussaint 1939:16). Many churches used thin alabaster panels instead (Romero de Terreros 1923:176; Toussaint 1974:145), and those in poor

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[260] AGN, Civil, vol. 350, exp. 2, fs. 40, 102, 130.
[261] AGN, Civil, vol. 1762, exp.11, f.10; it should be noted that the price of silver objects also depended on their weight.
[262] AGN, Civil, vol. 184, exp. 11 f. 90.
[263] AGN, Civil, vol. 184, exp. 11 f. 89.

neighborhoods, like the one in Barrio de San Pablo, in Puebla, would often have nothing protecting the windows from the elements (Fernandez de Echeverria y Veitia 1962 [1780]:234). Despite the high cost, flat glass was requested by churches for relic urns. Those that could afford it, like the San José parish in Puebla, protected the niche of an important figure with glass panels framed in silver. Some churches, not content with using any quality glass for this purpose, would order it from Naples. Such was the case of an altar niche in the Santa Cruz parish in Puebla. Important relics and figures in the Puebla cathedral were also kept in urns made of silver with glass panels (Fernandez de Echeverria y Veitia 1962 [1780]:99, 101, 223, 268, 390).

Window glass, particularly for large windows, remained a luxury throughout the Colonial period, and was mostly found in government and religious buildings. One example from 1666 is the room where public hearings took place in the Galería in the Real Audiencia, where the window frames had racks adjusted to them providing support to the glass windows (Sariñana y Cuenca 1666:13). Even in the late eighteenth century, glass windows were a symbol of wealth. The church of the Limpia Concepción in Puebla payed glassmaker Miguel Maldonado 42 pesos in 1723, for the manufacture of a stained glass window with the image of "Our Lady" (González Franco et al. 1994:249). Also, the glass windows in the house of Conde de Regla, in Mexico City, made up of 1722 pieces, amounted to 430 pesos in 1782 (Romero de Terreros 1923:177).

What becomes evident is that the value of glass varied tremendously in colonial Mexico depending on its type, the kind of artifact made of it, and its origin. Glass could be a trinket and the lowest form of currency, but at the same time a display of wealth when it reflected the trends in vogue in Europe or covered a large window. While colonial glassmakers were probably able to cover the needs for glass in New Spain and even to other parts of the Spanish empire, glass never stopped coming from Europe. There was demand for fine glass, as shown above, but it also came in the form of containers, as will be shown in the next section. This constant influx of glass had an impact on consumer preferences and consequently, on local production.

## 10.2. New Spanish Glass Production in Global Context

In the Early Modern period, people, objects, materials, technologies, and ideas traveled and circulated around the world like never before, generating a variety of responses and acquiring different meanings as they moved. Traveling goods had a direct impact on craft production and on the consumer demands of colonial societies as the variability and availability of new materials and objects increased. Migration was also a critical factor in the diffusion of knowledge. Eventually, these encounters, exchanges, interconnections, and trade resulted in a transformation of the existing corpus of objects and technologies, and in the creation of an entirely new world of goods (DuPlessis 1997:92; Findlen 2013:8, 15; Gerritsen and Riello 2016:4). Throughout the colonial period a variety of western commodities and luxury products traveled to the Americas in the Spanish galleons. Later, the Manila Galleon trade propelled New Spain into emerging global trade networks that greatly broadened the material diversity in the Americas and other regions that participated in transoceanic trade (Rubial García 1999:23).

As global trade networks expanded and became more complex, cities began to serve an important role by creating dynamic spaces where artisans, patrons, markets, consumers, and commodities interacted and influenced each other (Findlen 2013:8). In New Spain, the two main glass production centers were Mexico City and Puebla, the viceregal capital and the second largest city in the Spanish viceroyalty, respectively. Both cities were important hubs for merchants who transported products from the Manila Galleon along a commercial highway that connected Acapulco on the Pacific coast with Veracruz on the Atlantic side. Puebla was also an intermediate stop for merchants traveling in the other direction, from Veracruz to Mexico City, carrying products mainly from Spain, and other parts of Europe (Schurz 1985:310). The English Dominican friar Thomas Gage, who traveled in Mexico and Guatemala in the mid-seventeenth century describes Mexico City as follows:

> "Mexico is one of the richest cities in the world. By the North Sea cometh every year from Spain a fleet of near twenty ships laden with the best commodities not only of Spain but of the most parts of Christendom; by the south Sea it enjoyeth traffic from all parts of Peru. Above all, it trades with the East Indies, and from thence receiveth the commodities as well from those parts which are inhabited by Portuguese, as from the countries of Japan and China, sending every year two great caracas with two smaller vessels to the Philippine Islands, and having every year a return of such-like ships." (Gage 1969:65)

It is within this global context that glass production developed in colonial Mexico. Worldwide influences have shaped colonial glass production from its beginning. As mentioned in Chapter 6, the first glassmakers in the Americas came from different parts of the Iberian peninsula and some had lived in different places before moving to New Spain. European glass products never stopped arriving in the Americas. Venetian and Catalan glass was shipped to New Spain during the sixteenth century, followed by glass from the Nuevo Baztán workshop in Castile (Frothingham 1963:66-67; Gudiol and Artiñano 1935:78-79). In addition, glass in the form of mirrors, lamps, bottles for liqueurs and wine, flasks for spirits and medicine, tableware for daily use in the galleons, and boxes containing unspecified glass objects appear regularly in the cargo records of galleons bound to the Americas. Records of several galleons that departed to New Spain between the sixteenth and eighteenth centuries are preserved at the Archivo General de Indias (AGI) in Spain. Three different types of cargo can be distinguished in these records: 1) merchandise to be sold in commercial fairs or to be delivered to specific merchants in the port of destination; 2) the food supply and luggage of individual passengers known as *rancho*; and 3) the food supply and articles of daily use of the galleon's crew. The glass artifacts mentioned in these three types of cargo are discussed below.

The owners of ships and any person who shipped merchandise to the Americas were required to declare their goods to the *Casa de la Contratación*.[264] Records were made of everything that was included in the cargo of each galleon; these inventories were checked in two or three subsequent inspections. Anything that was not registered in the cargo records was confiscated (Castro y Bravo 1927:24-25). Examples of glass objects sent as merchandise in the cargo of Spanish galleons bound to Veracruz are listed in Table 10.

Table 10. Glass as merchandise in the cargo records of Spanish galleons bound for New Spain.

| **Galleon, nao, or frigate** | **Year** | **Glass merchandise** |
|---|---|---|
| Nuestra Señora de las Mercedes | 1695 | …3 *cajones toscos de espejos*… (3 rough boxes of mirrors)[265] |
| Santísima Trinidad | 1720 | …*2 cax[a]$^{s}$ de vidrieras*… (2 boxes of window/stained glass)<br>…22 *caxonsutos de espejos*… (22 small boxes of mirrors)<br>…*cax[a]s de vidros de luna*… (boxes of moon/mirror glass)[266] |
| Nuestra Señora de las Angustias, alias El Jasson | 1757 | …25 *cax[on]$^{es}$ toscos de vidrios*… (25 rough boxes of glass)<br>…60,, *cax[on]$^{es}$ toscos de vidrios*… (60 rough boxes of glass<br>…176 *cax[one]$^{s}$ de vidrios*… (176 boxes of glass) [267] |
| El Constante | 1757 | …260,, *frasqueras de licores*… (260 flask-cases of liqueurs)<br>…18 *frasqueras de vino*… (18 flask-cases of wine)<br>…6,, *frasqueras licores*… (6 flask-cases of liqueurs)[268] |
| El Gallardo | 1757 | …61,, *Caxones toscos de vidrios*…" (61 rough boxes of glass)[269] |
| Nuestra Señora del Rosario y Santo Domingo, alias el Alcon | 1757 | …3000..,, *Limetas de cerveza y sidra*… (3000 bottles of beer and cider)<br>…3090,, *Limetas de vino*… (3090 bottles of wine)[270] |

[264] House of Trade.
[265] AGI, Consulados, L.344, f. 65.
[266] AGI, Consulados, L.353, fs. 19v, 30, 39.
[267] AGI, Consulados 799, L.7, fs. 21, 24, 26.
[268] AGI, Consulados 799, L.7, fs. 47v, 49v, 55v.
[269] AGI, Consulados 799, L.7, f. 71.
[270] AGI, Consulados 799, L.7, fs. 84, 93v.

| | | |
|---|---|---|
| Begoña | 1772 | …*caxon de vidrios y christales*… (box of glass and crystal)[271] |
| Navio de 5 Gremios | 1772 | …*un caxon con un christal grande*… (a box with a large crystal)<br>…*Trescientos palmos dhos en caxones de vidrios de bucosidad*… (300 palms in boxes of glass of curved glass)[272] |
| San Vizente Ferrer | 1795 | …*16 caxones toscos de vasos*… (16 rough boxes of drinking cups)<br>…18 *cajones de vasos* … 7 *id de vidrios planos*… (18 boxes of drinking cups … 7 id of flat glass)[273] |

The glass sent as merchandise includes several mentions of mirrors, window/stained glass, tableware glass items such as drinking cups, as well as flasks and bottles of different alcoholic drinks. According to Frottingham (1963:59), during the eighteenth century box-loads of Central European glass, mirrors, and glassware from France and Flanders, crystal glasses from England, beer and wine bottles from Bristol and Bayonne, and fine tableware glass from the royal factory of La Granja de San Ildefonso were shipped to the Americas from the ports of Cadiz and Seville. Perhaps some of the *cajones de vidrio*, meaning boxes registered generically as containing glass, had some of the fine tableware shipped to the Americas. Deagan (1987:134) reports that French and Dutch bottles appear regularly in former Spanish colonies because Seville's New World trade system had a strong Germanic component that facilitated the movement of goods coming from areas north of Iberia. New Spain also received Bohemian glass during the late eighteenth and early nineteenth centuries, when many Bohemian glass factories established warehouses in cities throughout the world, including Cadiz, Seville, and across the Atlantic in at least six countries, including Mexico (Fernández 1990:104; Langhamer 2003:48). European merchandise arriving in Veracruz would then have been sold in the fair of Jalapa,

[271] AGI, Consulados, 806, legajo 17, f.6.
[272] AGI, Consulados, 806, legajo 3, f. 2v.
[273] AGI, Consulados, L. 371, fs. 2v, 3v.

where the merchants of New Spain bought items in bulk that they further sold at higher prices throughout the viceroyalty (Arcila Farías 1985:48-49). The pattern visible in the glass merchandise shipped to New Spain shows that people in Hispanic colonies came into contact with a variety of European glass articles that probably shaped their consumer preferences, which would in turn exert influence on local glassmakers trying to stay competitive.

A second category of cargo was the *rancho*. Passengers who were not part of the crew traveling in the galleons were responsible of bringing with them all the food and drink provisions, utensils, bedding, and other things that they needed for the trip to the Americas, which could take between two and three months depending on the port of destination (Castro y Bravo 1927:63; Martínez 1983:93). Table 11 shows some examples of the glass objects brought by individual passengers traveling to New Spain as part of their *rancho*. In many cases, the glass objects they brought with them functioned as containers for another product such as spices, sweets, medicines, and most frequently, alcoholic drinks.

Table 11. Examples of glass objects included in the rancho of individual passengers.

| **Galleon, nao, or frigate** | **Year** | **Glass in the *rancho* of individual passengers or families** |
|---|---|---|
| Nuestra Señora de Guadalupe (quicksilver warship) | 1722 | …*quatro frascos de azafrán*… (4 flasks of zafron)<br>…*frasqueras de mistela*… (flask-cases of *mistela*[274])<br>…*una frasquera de vino de Francia en ventiquatro frascos pequeños; otra frasquera del mismo p[receden]^te^ vacia; duzientas limetas de vino de Francia y sidra… tres frasqueras de agua ardientte la una rrefinada para remedios y las otras dos de los dos cozineros* … (a flask-case of French wine in twenty four small flasks; another empty flask-case of the same as before; two hundred bottles of French wine and cider … three flask cases of schnapps, one refined for remedies and the other two belonging to the cooks[275])<br>…*tres cajones de vidrios*… (three boxes of glass) |

[274] *Mistela* is the name of a sweet liquor typical of the regions of Catalonia and Valencia.
[275] This particularly rich *rancho* belonged to the Capitan of the ship, Lieutenant General Don Fernando Chacon.

| | | |
|---|---|---|
| | | …*una caja frasquera de mistela*… (one flask-case box of *mistela*)<br>…*quatro frasqueras de mistela*… (four flask-cases of *mistela*)<br>…*una cagitta frasqra con dose frascos de aguardiente; otra dha olandesa con el mismo genero*… (a small flask-case with twelve flasks of schnapps; another of the same from Holland with the same product)<br>…*Doze frasqueras*… (twelve flask-cases)<br>*...frasq[ue]ra de 20 frascos con vino nuo y ag[uardien]te*… (flask-case with 20 flasks of wine and schnapps)<br>…*dos frasqueras de misttela*… (two flask-cases of mistela)<br>…*una frasquera de aguard[ient]e*… (1 flask-case of schnapps)<br>…*frasquera con diferentes licores*… (flask-case with different liqueurs)<br>…*frasquera, papelera y otros trastes precissos*… (flask-case, paper-case and other precise kitchen frets)<br>…*tres frasqueras de mistela y dulzes*… (three flask-cases of *mistela* and sweets)<br>…*dos frasqueras, la una de diferentes aguas medicinales y la otra con mistela, aguardiente, agrio de sidra y asucar y unos dulces de chocolate* … (two flask-cases, one with different medicine waters and the other with *mistela*, schnapps, cider sour, and sugar and some chocolate sweets)<br>…*dos frasqueras con aguardiente y mistela*… (two flask-cases of schnapps and *mistela*…)<br>…*dos frasqueras... dos botellas de zerveza*… (two flask-cases… two bottles of beer)<br>…*una frasquera con vino 12 frascos; tres damachanas [damajuanas] de vino*… (a flask-case of wine 12 flasks; three demijohns of wine)<br>… *una frasquera pequeña con sorbets*… (a flask case with sherbets)<br>…*una frasquera con frascos de vino. 24 frascos*… (a flask-case with 24 flasks of wine)<br>…*Una frasquera con agrio de sidra y limon, con 12 frascos*… (a flask-case with cider and lemon sour, with 12 flasks)<br>…*una frasquera con mistelas y viscochos marcados con su apellido, con 6 frascos*... (a flask-case with *mistelas* and biscuits marked with his last name, with 6 flasks)<br>…*una frasquera de regalis y diferentes dulces*… (a flask-case of licorice and different candies)<br>… *otra caja [con] copas y garrafinas de cristal…una cajita con esta marca con pedazos de bidrios y* |

| | | |
|---|---|---|
| | | *cristales…3 limetas grandes con Malvasia de Siches…* (another box with crystal wine glasses and carafes… a small box with this mark with sherds of glass and crystal…3 large bottles with *malvasía de Sitges*[276])[277] …6 *frasqueras de mistela…* (6 flask-cases of mistela)[278] |
| Conde de Tolosa, alias La Tolosa (quicksilver fleet) | 1722 | *…24 frasqueras de mistela…* (24 flask-cases of *mistela*)<br>*…una caja frasquera de mistela…* (a flask-case box of *mistela*)<br>*…dos frasqueras pequeñas de mistelas…* (two small flask-cases of *mistelas*)<br>*…una caja frasquera con vevidas para poder hazer su viage en dho navio…* (a flask case with beverages to be able to make the trip in said ship)<br>*…una caja frasquera con diferentes cosas de repostería; y otra frasquera con vino y aguardiente…* (a flask-case with different bakery goods; and another flask-case with wine and schnapps)<br>*…dos frasqueras, una con 15 frascos de mistela, anizes y agrio de limón, otra de zedro con 12 frascos de vino y aguardiente, … vizcochos y vidrios para el uso de beber…* (two flask cases, one with 15 flasks of *mistela*, anise, and lemon sour, another one of cedar with 12 flasks of wine and schnapps,… biscuits and glasses to drink)<br>*…una frasquera de quinze frascos llenos de agrio de sidra, aguardiente, vinos y mistela…* (a flask-case with fifteen flasks full with cider sour, schnapps, wine, and *mistela*)<br>*…una frasquera, …media docena de vasos de cristal,… unos frascos de vino y otros de aguardiente en la frasquera…* (a flask-case,… half a dozen of crystal glasses,… some flasks of wine and others of schnapps in the flask-case)<br>*…un caxoncito con dose dosenas de vasos para el uso…* (a small box with twelve dozens of glasses for use)<br>*… una frasquera con quatro arrobas de chocolate y doze frascos de vinos y roselis…* (a flask case with four arrobas of chocolate and twelve flasks of wine and *roselis*[279])<br>*…un frasco de asafran para mi gasto…* ( a flask of zafron for my own use) |

[276] *Malvasía de Sitges* is a sweet wine from the town of Sitges in Catalonia.
[277] AGI, Contratación, 1295, N.1, R.2 (2), fs. 2v, 3, 6, 7, 8v, 11, 12, 14, 16, 17, 19, 21, 24, 31, 36v, 39, 39v, 41v, 43v.
[278] AGI, Contratación, 1295, N.1, R.2 (3), f. 15.
[279] *Roseli* could refer to resolí or rosolí, a sweet liquor typical of Cuenca and Andalucía, Spain.

| | | |
|---|---|---|
| | | …*una frasquera e nuebe frascos de vino*… (a flask-case and nine flasks of wine)<br>…*una frasq[ue]^ra de 9 frascos con diferentes licores*… (a flask-case with 9 flasks with different liqueurs)[280] |
| Nuestra Señora del Carmen and San Jorge | 1757 | …*2 frasqueras*… (2 flask-cases)[281] |
| La Divina Pastora, alias el Brillante | 1757 | …*1 Frasq[e]^ras licro[re]^s* … (1 flask-case of liqueurs)[282] |

While Spanish wine and schnapps were usually transported in barrels, wooden casks, and vats, the examples above show that wine coming from areas outside of Iberia, particularly from France and the Netherlands, came in bottles that were probably made and filled in the place of origin. Medicines and alcoholic drinks other than wine such as cider, beer, anise, and different types of sours were also transported in bottles, flasks, and vials that were usually packed in *frasqueras* or flask-cases. The references to French wine bottles, or flasks with schnapps from Holland illustrate how glass often traveled to the New World as a container. References to a variety of liqueurs from different regions of the Iberian peninsula in the *rancho* of families and individual passengers such as *mistela*, *malvasía de Sitges*, and *rosolí* sheds light on the consumer preferences of Spanish travelers of the time and their desire to retain European drinking habits. The sweet liqueur known as *mistela*, typical of the regions of Catalonia and Valencia, led in popularity just below wine and schnapps, which were sent in much larger containers. The mention of these regional liqueurs could also reflect economic changes that took place in the eighteenth century under the Bourbons, which culminated on a decree on free trade in 1778 that brought a wider variety of goods to the Spanish colonies (Fisher 1997:134).

The records of the galleons include a third category of cargo comprised of the maintenance supplies for the ship and the crew which include large quantities of glass for

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280 AGI, Contratación, 1295, N.1, R.3 (2), fs. 2, 6, 8, 10, 26, 33, 34, 36.
281 AGI, Consulados 799, L.7, f. 7.
282 AGI, Consulados 799, L.7, fs. 15v-16.

lanterns, drinking cups, and bottles of different kinds of alcoholic drinks such as beer, spirits, cider, and wine (Table 12).

Table 12. Examples of glass objects included in the supplies for the ship and its crew.

| **Galleon, nao, or frigate** | **Year** | **Glass in the supplies of the ship and its crew** |
|---|---|---|
| Fleet of the army of New Spain | 1565 | *…un farol de bedrieras cin su chapitell de cobre… una caxa con tres dozenas de vidrios para resipeto y una llave del farol…* (a glass lantern without copper capital… a box with three dozens of replacement glass and a key for the lantern)[283] |
| Santa Catalina | 1565 | *…El farol y caxa con tres dozenas de bidrios de rrespecto y la llave del farol… un farol roto o los bidros y la capella de cobre…* (the lantern and box with three dozens of replacement glass and the key of the lantern… a broken lantern or the glass and the copper capital)[284] |
| Santa María del Valle | 1572 | *…farol de bidrio con su capitel de cobre y pernos candeleros de fierro y una caxeta con bidros de respesto para lo adereçar … cien frasquillos de los susodhos son guarnecidos con sus cordones los noventa frascos y ochenta frasquillos de filo negro y blanco y los diez frascos y veinte frasquillos de filo negro y amarillo…* (glass lantern with a copper capital and bolts of iron, and a box with replacement glass to dress it … one hundred small flasks adorned with their laces the ninety flasks and eighty flasks with black and yellow edges) [285] |
| San Miguel | 1574 | *…un farol de bidrios con su capitel de cobre y su perno y candelero de cobre; una caxeta de vidrios de respeto para aderezar el dho farol…* (a glass lantern with its copper capitol and copper screw and candlestick; a box with replacement glass to dress said lantern)[286] |
| Nuestra Señora del Rosario y Santo Domingo, alias el Alcon | 1758 | *…2,, frasqueras regulares de mistelas; 1,, caxon con 200 frasquitos de var[io]s licores; 5,, caxoncitos con 300 limetas de vino de Francia; 2,, caxones con 60 docen[a]s de vasos grandes y chicos…* (2 regular flask cases of *mistela*; 1 box with 200 small flasks of various liqueurs; 5 small boxes with 300 bottles of French wine; boxes with 60 dozens of small and large drinking cups)<br>*…14 caxes de christales…* (14 boxes of crystal)<br>*…limetas de vino… limetas de cerveza y cidra… limetas de vino tinto de Manilba…* (wine bottles, bottles of beer and cider, bottles of red wine from Manilba[287])[288] |

[283] AGI, Contaduría, 290, f. 23.
[284] AGI, Contaduría, 290, f. 23.
[285] AGI, Contaduria 302, f. 1-198, fs. 117, 118.
[286] AGI, Contaduria, 423, N.2, f. 23v.
[287] Manilva is a region in Malaga, Spain.
[288] AGI, Consulados, L.364, f. 74v.

The glass mentioned in the cargo records of the galleons provide us with a glimpse of the variety of glass objects that were sent to New Spain throughout the colonial period. While it is impossible to know exactly the amount of glass that was imported or the kind of glass that came in the *cajones de vidrio*, the arrival of these goods provided colonial glassmakers a way to keep track of the glass made in Europe and adapt their products accordingly to remain competitive. External influences also came from bottles and flasks in which alcoholic drinks, sweets, medicines, and other products were transported. It is interesting to note that glass from the Americas may also have traveled to Europe, at least as containers. Passengers and crew certainly took food supplies for the return voyage. On the ship Hercules, a record was made of the *rancho* that was left over on the return trip from Veracruz in 1773, which included: 5 flasks of schnapps of a major brand and 3 dozens of drinking cups.[289] Similarly, cargo records of the ship San Rafael, which arrived in Cadiz from Veracruz in May of 1773, and could have come in the same fleet as the Hercules, include two empty flask-cases as part of the things to be disembarked from the ship.[290]

Restrictions may have been established to maintain the commercial monopoly in colonial trade, but the cargo records demonstrate that these rules did not stop glass and other products from traveling. This is reflected in the archaeological record. While most of the material recovered from excavations in Mexico usually corresponds to utilitarian artifacts such as generic bottles and vials that could have been produced locally, certain artifacts refer us to the Iberian peninsula and the rest of Europe. For example, enameled blue glass (Figure 155) and objects with helicoidal grooves found in both Mexico City and Puebla (Figure 156) reflect Catalan

[289] AGI, Contratación, 5804, L. 4, f. 28.
[290] AGI, Contratación, 5804, L. 4, f. 65.

influences. The chemical composition of the blue phial found in Mexico City, suggests it was of local manufacture, representing a colonial imitation of Catalan glass.


Figure 155. Enameled blue glass: a) two artifacts recovered in Barcelona, El Born CCM, early 18$^{th}$ century; b) Phial fragment recovered from the site Juárez 70 in Mexico City (photos: Karime Castillo).

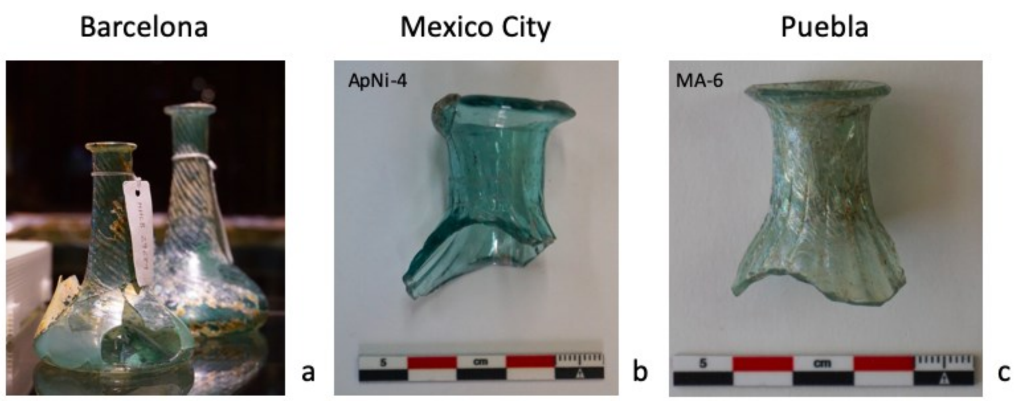


Figure 156. Glass objects decorated with helicoidal groves recovered in: a) Barcelona, b) Mexico City, and c) Puebla (photos: Karime Castillo).

One of the most visible imports in the archaeological material is Venetian style glass. We know from Chilton's story that this glass made its way to the Americas since the sixteenth century. It could come from Venice or from one of the places producing glass *á la façon de Venise*, which included Catalonia, France, Austria, Netherlands, and England (Page and Doménech 2004). The fragment of a wine glass found in Mexico City represents an example of Venetian glass (Figure 157a), while an enameled vessel also found in the viceregal capital probably represents Catalan glass *á la façon de Venise* imitating *latticinio* (Figure 157b).

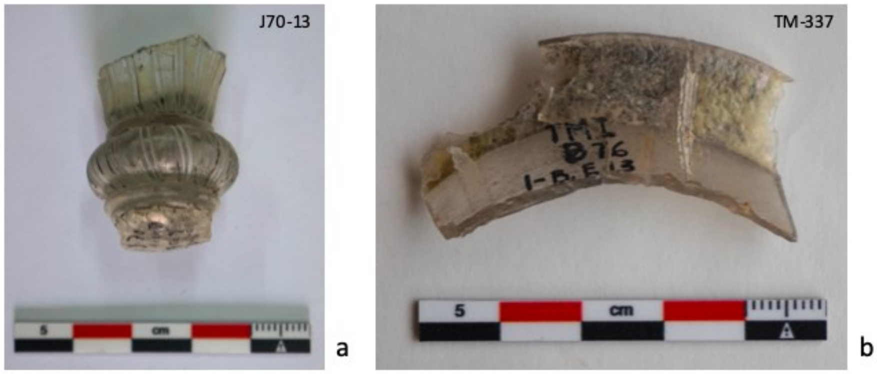


Figure 157. Fragment of a Venetian wine glass (a) and of a vessel à la façon de Venise (b) recovered in Mexico City (photos: Karime Castillo).

Another example of foreign influences recovered in Mexico City is opaque red copper glass (Figure 158b), which can be found in Germany in the fifteenth century (Drünert et al. 2018:376), in sixteenth-century Mallorca (Capellà Galmés 2015:171), and in late seventeenth century contexts in Barcelona (Figure 158a).[291] This type of glass has also been found in sixteenth century contexts in Venezuela and Florida (Deagan 1987:143).


Figure 158. Opaque copper red glass recovered in Barcelona (a) and Mexico City (b) (photos: Karime Castillo).

Fine tableware glass from the royal factory of La Granja de San Ildefonso was shipped to New Spain between 1760 and 1792 (Frothingham 1963:59; Pastor Rey de Viñas 1994:38, 67). Examples of fine glassware from La Granja are exhibited in several museums in Mexico that

[291] Examples of red copper glass can be found in the collections of El Born Centre de Cultura i Memòria, in Barcelona.

hold viceregal collections such as Museo Franz Mayer, Museo Soumaya (Figure 159a and 159b), and Museo Nacional de Arte Virreinal (Figure 159c).

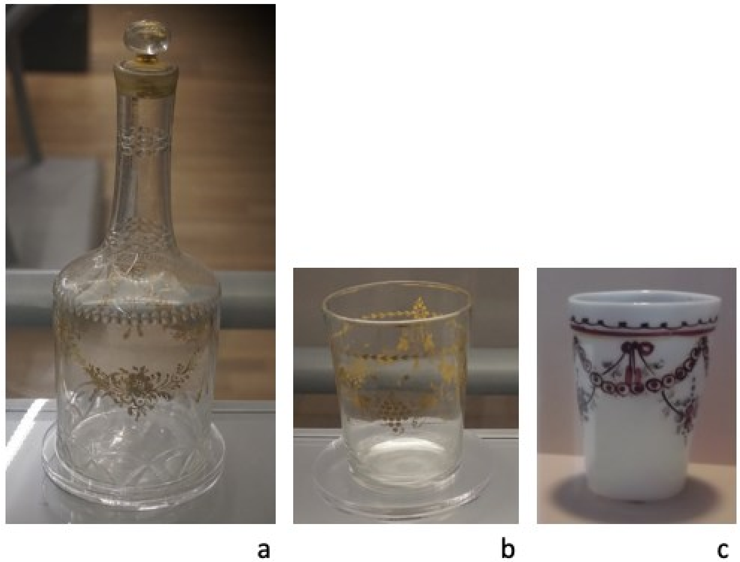

Figure 159. Glass from La Granja in the collections of Museo Soumaya (a, b) and Museo Nacional de Arte Virreinal (c) in Mexico City (photos: Karime Castillo).

New Spain also received Bohemian glass with engraved decoration during the late eighteenth and early nineteenth centuries, when many Bohemian glass factories established warehouses in cities throughout the world, including Mexico (Fernández 1990:104). Examples of engraved Bohemian glass and/or *à la façon de Boheme* have been recovered in excavations in Mexico City (Figure 160). Among the samples analyzed was J70-15, which has a composition typical of potash glass and probably represents a European import.[292] Engraved glass from both La Granja and Bohemia had an important influence in local glassmaking and its imitations derived in a type of popular glass known today as *vidrio de pepita*.

[292] The other artefacts in the image were not analyzed.

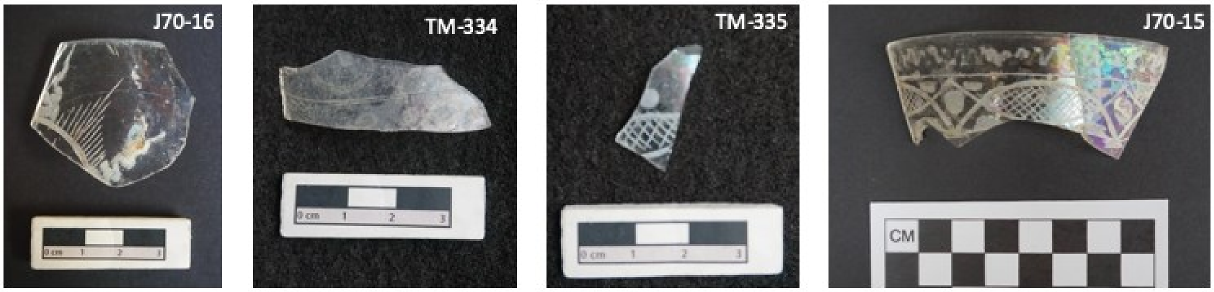


Figure 160. Examples of engraved glass in Bohemian style recovered in Mexico City (photos: Karime Castillo).

The periodic arrival of galleons kept objects moving, influencing the taste and desires of the local population. Venetian style glass was probably used by the elite of New Spain as a marker of status and European ways of life. Being one of the most sought-after products in early modern Europe, its presence in the New World is expected. As tendencies shifted in Europe, other types of glass, such as Bohemian engraved glass made in Bohemia and La Granja, became the favorites of New Spanish elites. Local craftsmen were probably influenced by the arrival of foreign glass products. Considering the fragility of glass, and the roughness of the long journey from Europe to major cities in Spanish America, adapting manufacture to respond to colonial consumer demands would have proved profitable for colonial glassmakers.

10.3. Colonial Mexican Glass beyond New Spain

In the sixteenth century, as the glassmaking industry slowly took root in the New World, three kinds of glass where reportedly made in Puebla: crystal white, green, and blue, which were exported as far as Guatemala and Peru (Fernández 1990:47; Frothingham 1963:59). Mexico City was also becoming a major glass production center in the mid-sixteenth century, when trade between New Spain and Peru through the port of Acapulco was relatively abundant. This trade route allowed glass from New Spain to travel south, but trade began to decline around the decade of 1580 when commerce with Asia took priority. Additional import and export restrictions were established in the early seventeenth century, and by 1631 the Spanish crown had prohibited any kind of trade between Mexico and Peru (Fernández 1990:50; Fisher 1997:65-66).

Despite trade restrictions, the glass industry continued growing during the seventeenth century. Archaeological finds indicate that New Spanish glass was probably sent to Florida as part of the supplies sent to the missions via the Florida *situado*[293] (Deagan 1987:139). While the number of glass artisans in Puebla seems to have been smaller than in Mexico City, the glass workshops of Puebla were sometimes selected for important commissions, such as the 300 glass grenades that the viceroy ordered in 1679 to be made in Puebla and sent to the presidio in Santiago de Cuba mentioned in Chapter 6.[294]

In the eighteenth century, shipments of glassware from New Spain to Cuba and Florida continued, while eastbound galleons took glassware to Puerto Rico and Venezuela along with other New Spanish products such as cacao, ceramics, textiles, and soap (Fernández 1990:94; Ulloa 1999:53). The cargo of the ship Rayo de Viscaya that traveled from Veracruz to Havana in April 1756 included fifty dozen ordinary glasses from Puebla. Another record from the same year, indicates that 282 dozen glasses were shipped in the packet-boat San Judas Thadeo from Puebla to Maracaibo, Havana, and Caracas, while the ship Nuestra Señora del Pilar took thirty dozen glasses from Puebla to Caracas and Havana in the same year (Fernández 1990:96, 239).

New Spanish glass seems to have crossed the Pacific ocean as well. From 1573 to 1715, the Manila Galleon sailed once a year from Acapulco to Manila and back (Schurz 1985:21; Skowronek 1998:47). The movement of people, goods, and ideas between New Spain and the Philippines by way of the Manila galleon trade introduced transformations that changed social

[293] Annual government subsidy.
[294] AHMP, Expedientes, Vol. 152, L. 1517: 96-97.

behavior, religion, fashion, commerce, and the daily lives of many people in Spanish Americas and the Philippines (Suárez Soler 2015:68-69). The main products shipped from New Spain to the Philippines were silver, agricultural produce, and articles from Spain and colonial Mexico needed by the Spanish colonists and the Church, such as wine, olive oil, wheat, cacao, cochineal, soap, books, lace, fans, and ironware (Bjork 1998:41; Skowronek 1998:58; Suárez Soler 2015:65, 70, 91). Other products that made their way from New Spain to the Philippines that do not always appear in galleon cargo records, include ceramic and glass containers holding the above-mentioned items, objects carried by the crew as personal possessions, and utensils used on board the galleons, which took three months to reach Manila from Acapulco.

Glass does not seem to have been produced in the Philippines during the colonial period, although it has been found in archaeological excavations in Manila and other parts of the Philippines (e.g., Cruz 2014). This suggests that glass was imported either from China, or from Europe and New Spain through the Manila galleon trade. Regalado (1987:804) reports that a scarcity of glass in the Philippines promoted the use of panes made of thin clams called *capiz* to cover windows, but it is unknown for how long this practice endured.

A petition to the Spanish king in 1609 indicates that, in fact, glass was sent to the Philippines from New Spain. In this petition, Hernando de los Ríos, a government official based in the Philippines, requested that a glassmaker be sent to the islands because they obtained all their glass from New Spain and it was very expensive. The petition states:

> Sir.
>
> Hernando de los Ríos, Coronel General Procurator of the Philippines says: that in that realm there is much need for glass because it is brought from New Spain and they do not know how to make it in China so there is a lot of scarcity of it and it is very expensive, there are materials to make it. I beg your Majesty to be merciful to that realm and give it license to take an officer glassmaker that will receive mercy in that and that he can be married or single however he can be found.
>
> Give the license [rubric].

On 10 of April 1609
The General Procurator of the Philippines"
(author's translation).[295]

While the shipments of glass to South America indicate that glassmakers in colonial Mexico produced a surplus to fulfill the demand of glass by other Spanish colonies in the American continent, Hernando de los Rios' petition suggests that their products traveled much further to supply the Spanish settlements in the Philippines. Martins Torres (2019a:470-471) located documentation that authorized glassmaker Alonso de la Torre, from Seville, to travel to the islands in 1610 to serve the General Procurator, and she suggests that he may have been employed in the making of glass lenses. Another glassmaker who spent two years in the Philippines in the early eighteenth century was Andres Monroy, Spanish and resident of Mexico City (Martins Torres 2019a:475), but it is unknown if he practiced his craft while he was in the islands.

Glass has been found at the shipwreck sites of Manila galleons such as Nuestra Señora de la Concepción, which sank in 1638 (Junco Sanchez 2011:2), as well as the Spanish warship San Diego, which sank near Fortune Island in 1600 after a naval battle with a Dutch fleet. The San Diego had been sent to the area after the aforementioned fleet arrival in the Philippines to protect the San Tomás galleon that came from Acapulco loaded with silver (Cuevas 1996:197, 200; Goddio 1996:50). Among the many artifacts found in the shipwreck, there were tableware and drinking glasses including one cylindrical goblet, the remains of a flute glass, two specimens of cups or *tazas*, and one bottle (Provoyeur 1996:258, 261).

The trade of glass in the Philippines remains a subject to be studied. There are very few publications that refer to glass (Skowronek 1998:67) and only one study fully devoted to

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[295] AGI, Filipinas, 36, No. 44, f. 485-585v.

archaeological glass from the Philippines has been published (Cruz 2014).[296] The latter examined a collection of glass recovered from the Pinagbayanan site, in San Juan, Batangas focusing mainly on imported glass bottles from the nineteenth century, although flat glass is also mentioned (Cruz 2014:30).

The movement of people and goods between Europe, New Spain, and the Philippines by way of the Spanish fleets and the Manila galleon trade brought about lifestyle transformations that, rather than being unilateral or univocal, had a decided impact on the lives of many people in Spain, Spanish America, and the Philippines (Gerritsen and Riello 2016:16, 19; Suárez Soler 2015:68-69). The Early Modern era brought about a tremendous growth in the production and distribution of all kinds of objects and materials; however, even as objects traveled, often serving as material ambassadors, they did not lose their local connections, but rather continued reinforcing identities or building new ones (Lichtenstein 2013:375, 377). The study of material culture and technology from a global perspective can reveal complex linkages across spaces, shifts in meaning that different artifacts assumed within and in between these spaces, and cultural changes brought by the movement of people and objects characteristic of the Early Modern period (Gerritsen and Riello 2016:16).

Glass in New Spain, both as a technology and as a product, was from the beginning the result of a complex technology developed in Spain with influences from other parts of Europe and the Islamic world. Once the technology took root and began to flourish in New Spain, glass continued to be subject to global influences and, in turn, may have influenced products in the Caribbean, Central and South America, and the Philippines.

[296] For research on glass beads in the Philippines see Martins Torres (2019a), Bellina (2003), and Cayron (2006).

## 10.4. Concluding Remarks

The study of the transfer of glass technology to the Americas would not be possible by using a single line of evidence. While historical documents are a rich source of information and they are crucial in recovering information about the social aspects of a technology, they leave room for interpretation and do not provide all the answers, especially regarding technological aspects. For instance, documentation of glassmaking in Mexico City is very rich thanks to the records of the Casa del Apartado and the lawsuit started by Doña Micaela. But despite providing information about raw materials, tools, and even some technical aspects of glassmaking, they do not fully explain the use of raw materials and can even be misleading. For example, the frequent mention of *tequesquite* in inventories and expense records could be read as an indication of its prevalence over other alkali sources like plant ash. At the same time, the ambiguity of terms like *barrilla*, which may represent several species of plants, cannot be resolved without taking into account the characteristics needed in the plant to make it suitable for glassmaking and performing the appropriate analyses.

Looking at archaeological glass collections in combination with thorough historical research, opens more opportunities for richer and better-sustained interpretations, but in terms of addressing technological aspects, this combination is still not sufficient. To really understand a technology it is important to experience it in the most direct way possible. Ethnographic observations are one way to do this. By observing the different parts of a technological process and discussing it with experienced practitioners, it is possible to access knowledge that will be difficult to find in historical records and impossible to detect from an archaeological collection alone. One example of this is apprenticeship. While historical documents may indicate the amount of years that an apprentice will spend learning the craft, aspects like the mode of instruction or the stages of learning can be better understood by observing the practices in a workshop and discussing them with the specialists or by becoming an apprentice oneself.

Moreover, in the particular case of archaeological glass, the scientific analysis is crucial to study the technology behind it. Only by obtaining information on the chemical composition of the glass is it possible to discuss raw material selection and identify technological traditions. However, scientific analysis alone cannot inform us about the social or symbolic aspects of a technology or the people behind it.

The multidisciplinary approach used in this research allowed to thoroughly investigate the transfer of glass technology to the Americas. Results on the chemical composition of archaeological glass from both Mexico City and Puebla are presented for the first time. Although there are many limitations to this study, such as the disturbed secondary contexts of Mexico City, and the small size of the collection of glass from Puebla, this study provides a foundational stone in the study of archaeological glass in the Spanish Americas. As more glass collections are studied, and more raw materials are investigated a clearer picture of the adaptation process will emerge. From this study alone, we can already notice certain differences between the glass from Mexico City and Puebla, although the analysis of many more glass collections is needed to be certain. The study also indicates that it is possible to distinguish American from European glass based on the study of sand sources and possibly the plant ashes as well. It should also be noted that the analysis of Catalan glass is also the first one to be made.

The research showed that colonial glassmakers relied on local resources to make glass in New Spain, and while they followed the Iberian tradition of glassmaking based on the use of halophyte plant ash as the source of alkali, they sometimes struggled obtaining glass of sufficient quality. When this happened, they adapted by using a second source of local alkali, *tequesquite,* an evaporite similar to natron, that was not used in Spain. The archaeological material confirmed the preference for the use of plant ash as the fluxing agent, but it also suggests the combined use of plant ashes and *tequesquite*, or the use of different types of halophyte plants.

Most importantly, the research showed that the transfer of glass technology would not have been possible without the reliance on the traditional ecological knowledge of indigenous communities, who had been exploiting some of the raw materials needed for glassmaking since prehispanic times: *tequesquite* for certain and possibly *barilla* as well, if the suggested species were indeed the ones used. The analyses of more halophyte plant species, including those suggested by other researchers, is needed to confirm this. What remains certain is that glassmakers relied on these communities and their knowledge to obtain two crucial resources for glassmaking. The success of this industry would have been impossible without them.

# APPENDIX 1. GLASS SAMPLES ANLAYZED

| **Location** | **Site** | **Object ID** | **Date (century)** | **Artifact** | **Color** | **Image** |
|---|---|---|---|---|---|---|
| Mexico City | Juarez 70 | J70-2 | 19th | Wine Bottle embossed "Manning & Marshall" | Dark green |  |
| Mexico City | Juarez 70 | J70-10 | 18th-19th? | Production Waste (glass flow) | Aquamarine |  |
| Mexico City | Juarez 70 | J70-11 | 18th? | Phial | Green |  |
| Mexico City | Juarez 70 | J70-13 | 17th? | Wine Glass | Colorless with white stripes |  |

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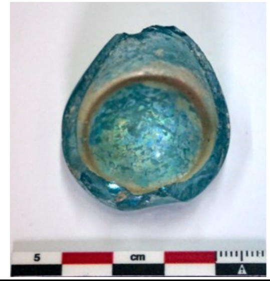
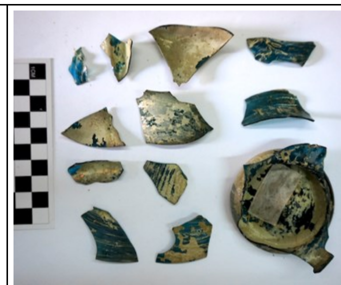
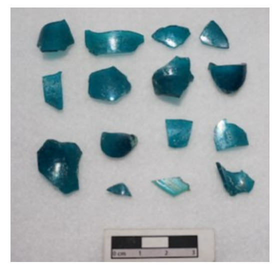
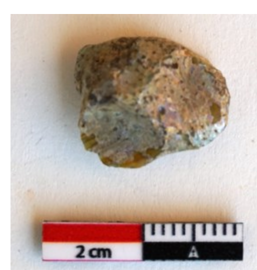
|---|---|---|---|---|---|---|
| Mexico City | Juarez 70 | J70-14 | 18th? | Phial | Light blue |  |
| Mexico City | Juarez 70 | J70-15 | 18th-19th? | Vase/bowl | Colorless, engraved |  |
| Mexico City | Juarez 71 | J70-17 | 18th? | Bottle | Colorless |  |
| Mexico City | Juarez 72 | J70-18 | 18th-19th? | Production Waste (dripping) | Colorless with a yellow tint |  |
| Mexico City | Juarez 70 | J70-19 | 17th-18th | Phial | Dark blue glass and white enamel |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mexico City | Juarez 70 | J70-20 | 17th-18th | Vessel | Blue |  |
| Mexico City | Juarez 70 | J70-21 | 18th? | Phial | Aquamarine |  |
| Mexico City | Juarez 70 | J70-23 | 18th-19th? | Phial | Colorless with a yellow tint |  |
| Mexico City | Juarez 70 | J70-24 | 18th-19th? | Production Waste (Chunk) | Green and blue |  |
| Mexico City | Juarez 70 | J70-26 | 18th-19th | Bottle/Phial | Colorless with a dark yellowish tint |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mexico City | Juarez 70 | J70-27 | 18th | Bottle/Phial | Aquamarine |  |
| Mexico City | Juarez 70 | J70-32 | 19th | Wine Bottle embossed: "H·Ricketts & Co :·: Glassworks Bristol" | Dark green |  |
| Mexico City | Juarez 70 | J70-35 | 18th-19th | Bottle | Dark green |  |
| Mexico City | Juarez 70 | J70-40 | 19th | Wine Bottle | Dark green |  |
| Mexico City | Juarez 70 | J70-44 | 19th | Seal of a wine bottle "B DANGLADE MEDOC" | Dark green |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mexico City | Juarez 70 | J70-46 | 19th | Seal of a wine bottle "MADEIRA" | Dark green |  |
| Mexico City | Templo Mayor | TM-32 | 19th? | Wine glass | Colourless |  |
| Mexico City | Templo Mayor | TM-38 | Unknown | Vessel | Greenish blue |  |
| Mexico City | Templo Mayor | TM-48 | 18th-19th? | Production Waste (chunk) | Green |  |
| Mexico City | Templo Mayor | TM-49 | 18th-19th? | Production Waste (dropletts) | Green |  |
| Mexico City | Templo Mayor | TM-50 | 18th-19th? | Production Waste (chunk) | Yellow-green |  |

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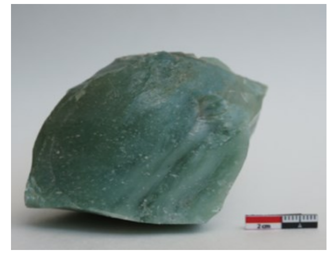
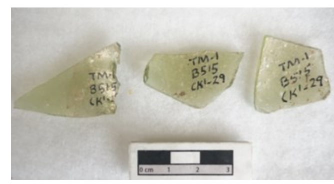
|---|---|---|---|---|---|---|
| Mexico City | Templo Mayor | TM-53 | 18th-19th? | Production Waste (chunk) | Aquamarine |  |
| Mexico City | Templo Mayor | TM-120 | 18th-19th? | Production Waste (chunk) | Green |  |
| Mexico City | Templo Mayor | TM-135 | 18th-19th? | Vessel | Light Green |  |
| Mexico City | Templo Mayor | TM-142 | 18th? | Bottle/Phial | Aquamarine |  |
| Mexico City | Templo Mayor | TM-150 | 18th-19th? | Phial | Light green |  |
| Mexico City | Templo Mayor | TM-152 | 18th-19th? | Phial | Green |  |

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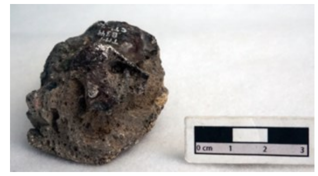
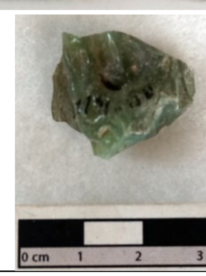
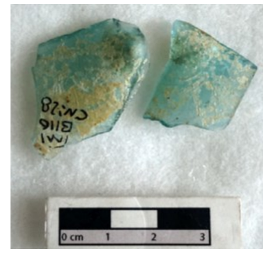
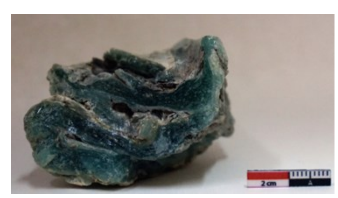
|---|---|---|---|---|---|---|
| Mexico City | Templo Mayor | TM-180 | 18th-19th? | Kiln waste | Ceramic with glass and charcoal |   |
| Mexico City | Templo Mayor | TM-230 | 18th-19th? | Production Waste (chunk) | Green-blue |  |
| Mexico City | Templo Mayor | TM-231 | 18th-19th? | Production Waste (chunk) | Green-blue |  |
| Mexico City | Templo Mayor | TM-232 | 18th-19th? | Production Waste (chunk) | Green-blue |  |
| Mexico City | Templo Mayor | TM-234 | 18th-19th? | Production Wate (dripping) | Green |   |
| Mexico City | Templo Mayor | TM-235 | 18th-19th? | Production Waste (chunk) | Yellow |   |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mexico City | Templo Mayor | TM-300 | 18th-19th? | Vessel | Aquamarine |  |
| Mexico City | Templo Mayor | TM-303 | 18th? | Bottle/Phial | Aquamarine |  |
| Mexico City | Templo Mayor | TM-310 | 18th? | Drinking/wine glass | Aquamarine |  |
| Mexico City | Templo Mayor | TM-337 | 17th-18th? | Jar | Colourless |  |
| Mexico City | Templo Mayor | TM-360 | 18th-19th? | Production Waste (dripping) | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-2 | 18th-19th? | Production Waste | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-3 | 18th-19th? | Production Waste (chunk) | Light green |  |

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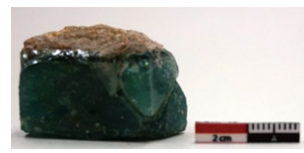
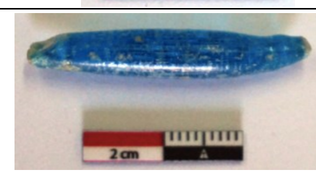
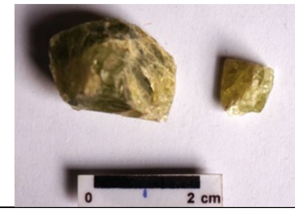
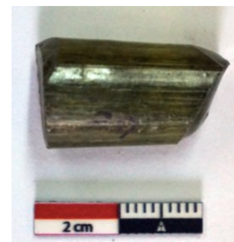
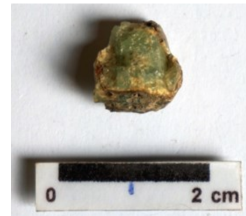
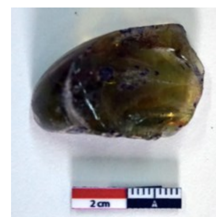
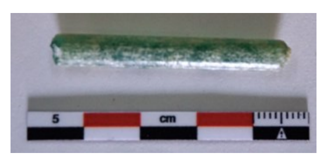
|---|---|---|---|---|---|---|
| Mexico City | Bolivia 16 | B16-4 | 18th-19th? | Production Waste (chunk/posta) | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-5 | 18th-19th? | Production Waste (chunk) | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-6 | 18th-19th? | Production Waste (chunk) | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-8 | 18th-19th? | Production Waste (dripping) | Green |  |
| Mexico City | Bolivia 16 | B16-9 | 18th-19th? | Producton Waste (droplet) | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-10 | 19th? | Rod | Blue |  |
| Mexico City | Bolivia 16 | B16-11 | 18th-19th? | Producton Waste (droplet) | Green |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mexico City | Bolivia 16 | B16-12 | 18th-19th? | Production Waste (chunk) | Green |  |
| Mexico City | Bolivia 16 | B16-13 | 18th-19th? | Production Waste (trail) | Green |  |
| Mexico City | Bolivia 16 | B16-14 | 19th? | Rod | Green |  |
| Mexico City | Bolivia 16 | B16-15 | 18th-19th? | Production Waste | Green |  |
| Mexico City | Bolivia 16 | B16-16 | 18th-19th? | Production Waste (chunk) | Blue-green |  |
| Mexico City | Bolivia 16 | B16-17 | 18th-19th? | Production Waste (chunk) | Light green |  |
| Mexico City | Bolivia 16 | B16-18 | 18th-19th? | Production Waste (chunk) | Green |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mexico City | Bolivia 16 | B16-19 | 18th-19th? | Production Waste (chunk) | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-20 | 18th-19th? | Production Waste (chunk) | Light green |  |
| Mexico City | Bolivia 16 | B16-25 | 19th? | Chunk/Vessel | Colorless |  |
| Mexico City | Bolivia 16 | B16-26 | 18th-19th? | Posta?/vessel | Green |  |
| Mexico City | Bolivia 16 | B16-27 | 18th-19th? | Phial/bottle | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-28 | 18th-19th? | Phial/bottle | Blue |  |
| Mexico City | Bolivia 16 | B16-29 | 19th? | Rod | Green |  |
| Mexico City | Bolivia 16 | B16-30 | 18th-19th? | Production Waste (dripping) | Green |  |

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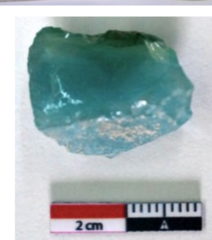
|---|---|---|---|---|---|---|
| Mexico City | Bolivia 16 | B16-31 | 18th-19th? | Production Waste (chunk) | Aquamarine and green |  |
| Mexico City | Bolivia 16 | B16-32 | 18th-19th? | Production Waste (chunk) | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-33 | 18th-19th? | Production Waste (chunk) | Green |  |
| Mexico City | Bolivia 16 | B16-34 | 18th-19th? | Production Waste (chunk) | Green |  |
| Mexico City | Bolivia 16 | B16-35 | 18th-19th? | Production Waste (chunk) | Green |  |
| Mexico City | Bolivia 16 | B16-36 | 18th-19th? | Production Waste (chunk) | Green and purple |  |
| Mexico City | Bolivia 16 | B16-37 | 18th-19th? | Production Waste (chunk) | Aquamarine (opaque) |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mexico City | Bolivia 16 | B16-38 | 18th-19th? | Production Waste (chunk) | Blue-green |  |
| Mexico City | Bolivia 16 | B16-41 | 19th-Early 20th? | Rod | Black |  |
| Mexico City | Bolivia 16 | B16-44 | 19th? | Phial | Colorless with a yellow tint |  |
| Mexico City | Bolivia 16 | B16-46 | 18th? | Phial/Vase | Colorless with a yellow tint |  |
| Mexico City | Bolivia 16 | B16-48 | 18th-19th? | Phial | Light green |  |
| Mexico City | Bolivia 16 | B16-49 | 18th-19th? | Production Waste (chunk) | Aquamarine |  |
| Mexico City | Bolivia 16 | B16-50 | 19th? | Rod | Black |  |

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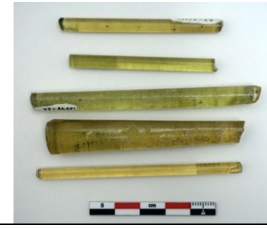
|---|---|---|---|---|---|---|
| Mexico City | Bolivia 16 | B16-51 | 19th? | Rod | Yellow |  |
| Mexico City | Bolivia 16 | B16-52 | 19th? | Rod | Green |  |
| Mexico City | Bolivia 16 | B16-53 | 19th? | Rod | Blue |  |
| Mexico City | Bolivia 16 | B16-54 | 19th? | Rod | Amber |  |
| Mexico City | Bolivia 16 | B16-55 | 19th? | Rod | Green |  |
| Mexico City | Bolivia 16 | B16-56 | 19th? | Rod | Dark blue |  |
| Mexico City | Bolivia 16 | B16-58 | 19th? | Rod | Purple |  |

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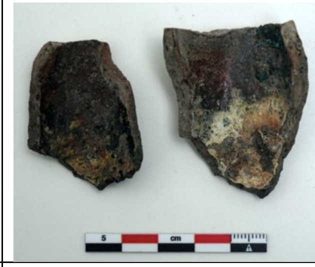
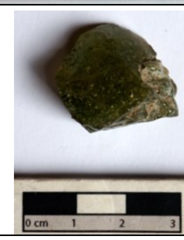
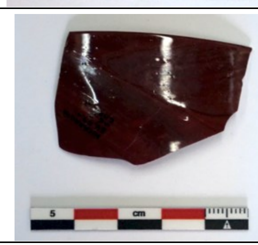
|---|---|---|---|---|---|---|
| Mexico City | Bolivia 16 | B16-63 | 19th? | Production Waste (crucible residue) | Ceramic with glass residue |  |
| Mexico City | Bolivia 16 | B16-75 | 18th-19th? | Production Waste (chunk) | Dark red |  |
| Mexico City | Apartado/ Nicaragu a | ApNi-2 | 18th-19th? | Production Waste (chunk) | Green |  |
| Mexico City | Apartado/ Nicaragu a | ApNi-3 | 18th-19th? | Production Waste (chunk) | Colorless with a yellow tint |  |
| Mexico City | Apartado/ Nicaragu a | ApNi-4 | 18th-19th | Phial | Aquamarine |  |
| Mexico City | Apartado/ Nicaragu a | ApNi-7 | 18th-19th? | Production Waste (chunk) | Green |  |
| Mexico City | Apartado/ Nicaragu a | ApNi-8 | 18th | Bowl | Dark red |  |

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|---|---|---|---|---|---|---|
| Mexico City | Apartado/ Nicaragu a | ApNi-9 | 18th-19th | Phial | Yellow |  |
| Mexico City | Apartado/ Nicaragu a | ApNi-10 | 19th-Early 20th? | Phial | Colorless (grey tint) |  |
| Mexico City | Apartado/ Nicaragu a | ApNi-11 | 19th-Early 20th | Phial | Colorless |  |
| Mexico City | Apartado/ Nicaragu a | ApNi-13 | 19th-Early 20th | Vessel | Blue |  |
| Mexico City | Libertad 35 | Li35-3 | 19th | Wine bottle seal, embossed "St JULIEN MÉDOC" | Olive green |  |
| Mexico City | Libertad 35 | Li35-4 | 19th | Wine bottle seal, embossed: "CHATEAU LEOVILLE" | Olive green |  |
| Mexico City | Libertad 35 | Li35-5 | 19th | Wine bottle seal, embossed "PAUILLAC MÉDOC" | Olive green |  |

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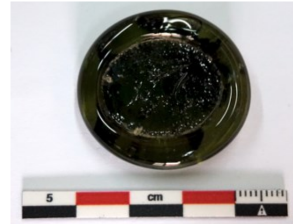
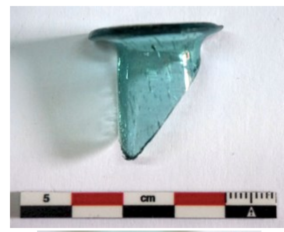
|---|---|---|---|---|---|---|
| Mexico City | Libertad 35 | Li35-6 | 19th? | Wine bottle seal, embossed: "R & C" | Olive green |  |
| Mexico City | Libertad 35 | Li35-7 | Late 19th | Vessel, embossed: "Bristol" | Light aquamarine |  |
| Mexico City | Libertad 35 | Li35-8 | Unknown | Phial | Blue-green |  |
| Mexico City | Libertad 35 | Li35-9 | Unknown | Bottle | Blue |  |
| Puebla | Museo Amparo | MA-2 | 18th? | Phial | Aquamarine |  |
| Puebla | Museo Amparo | MA-3 | 19th? | Wine glass | Colorless |  |
| Puebla | Museo Amparo | MA-4 | 18th? | Phial/waster | Black/purple |  |

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|---|---|---|---|---|---|---|
| Puebla | Museo Amparo | MA-5 | Late 19th-Early 20th | Vessel | White and Pink |  |
| Puebla | Museo Amparo | MA-6 | 19th | Phial | Aquamarine |  |
| Puebla | Museo Amparo | MA-7 | 19th | Phial | Aquamarine |  |
| Puebla | Museo Amparo | MA-8 | Late 19th-early 20th century | Phial, embossed: "DR. BELL'S PINE - TAR - HONEY FOR COUGHS AND COLDS" | Aquamarine |  |
| Puebla | Museo Amparo | MA-9 | Late 18th-19th? | Steamware | Colorless |  |
| Puebla | Museo Amparo | MA-10 | Early 19th | Wine glass | Colorless |  |
| Puebla | San Juan de Dios Church | SJD-2 | 18th? | Vessel/phial | Aquamarine |  |

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|---|---|---|---|---|---|---|
| Puebla | San Juan de Dios Church | SJD-5 | 18th-19th | Vessel/bottle | Green |  |
| Puebla | San Juan de Dios Church | SJD-7 | 18th? | Flat glass | Aquamarine |  |
| Puebla | San Juan de Dios Church | SJD-9 | 18th? | Vessel | Aquamarine |  |
| Puebla | San Juan de Dios Church | SJD-10 | 18th? | Vessel | Blue |  |
| Puebla | San Juan de Dios Church | SJD-11 | 18th | Flat glass | Colorless |  |
| Puebla | San Juan de Dios Church | SJD-12 | 18th | Vessel | Blue |  |
| Puebla | San Juan de Dios Church | SJD-13 | 18th? | Vessel/phial | Aquamarine |  |

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|---|---|---|---|---|---|---|
| Puebla | San Juan de Dios Church | SJD-14 | 18th? | Vessel | Colorless |  |
| Puebla | San Juan de Dios Church | SJD-15 | 18th? | Flat glass | Colorless |  |
| Puebla | San Juan de Dios Church | SJD-19 | 18th-19th | Vessel | Blue |  |
| Puebla | San Juan de Dios Church | SJD-20 | 18th-19th | Vessel | Colorless |  |
| Puebla | San Juan de Dios Church | SJD-21 | 18th? | Vessel | Colorless |  |
| Puebla | San Juan de Dios Church | SJD-25 | 18th? | Vessel | Aquamarine |  |
| Puebla | San Juan de Dios Church | SJD-26 | 18th-19th | Vessel | Colorless |  |

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|---|---|---|---|---|---|---|
| Puebla | San Roque Church | SR-3 | 18th | Bottle | Amber |  |
| Puebla | Huerta del Obispo | HO-2 | Late 18th | Wine glass | Colorless |  |
| Puebla | Huerta del Obispo | HO-3 | Late 18th | Vessel | Aquamarine |  |
| Barcelona | Carrer Antic de St Joan | BCN-2 | 18th | Vessel | Aquamarine |   |
| Barcelona | Carrer Antic de St Joan | BCN-3 | 17th-18th | Vessel | Colorless (yellow tint) |   |
| Barcelona | Carrer Antic de St Joan | BCN-4 | 18th | Flat glass | Aquamarine |  |
| Barcelona | Carrer Antic de St Joan | BCN-5 | 18th | Complex Vessel | Colorless |  |
| Barcelona | Carrer Antic de St Joan | BCN-6 | 18th | Vessel | Aquamarine |   |

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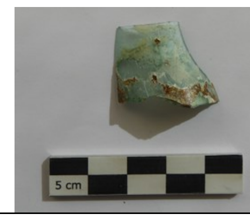
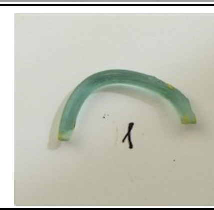
|---|---|---|---|---|---|---|
| Barcelona | Carrer Antic de St Joan | BCN-7 | 18th | Complex Vessel | Colorless |  |
| Barcelona | Carrer Antic de St Joan | BCN-8 | 17th-18th | Wine glass | Colorless |   |
| Barcelona | Carrer Antic de St Joan | BCN-10 | 17th-18th | Complex Vessel | Colorless |   |
| Barcelona | Carrer Antic de St Joan | BCN-11 | 17th-18th | Vessel | Aquamarine |   |
| Barcelona | Carrer Antic de St Joan | BCN-12 | 17th-18th | Wine glass | Colorless |   |
| Barcelona | Carrer Antic de St Joan | BCN-13 | Late 17th-Early 18th | Trail application | Aquamarine |   |
| Barcelona | Carrer Antic de St Joan | BCN-14 | Late 17th-Early 18th | Vessel | Aquamarine |   |
| Barcelona | Carrer Antic de St Joan | BCN-15 | 18th | Bottle | Green |  |

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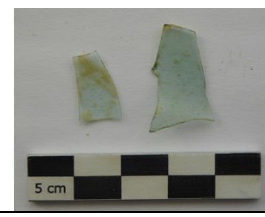
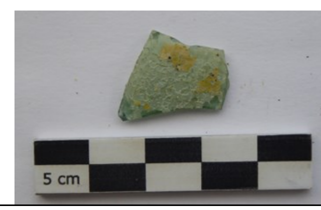
|---|---|---|---|---|---|---|
| Barcelona | Carrer Antic de St Joan | BCN-17 | 17th | Complex Vessel | Colorless |  |
| Barcelona | Carrer Antic de St Joan | BCN-18 | 17th-18th | Wine glass? | Colorless (yellowish tint) |  |
| Barcelona | Carrer Antic de St Joan | BCN-19 | Late 17th-Early 18th | Wine glass | Colorless |  |
| Barcelona | Carrer Antic de St Joan | BCN-20 | Late 17th-Early 18th | Vessel | Aquamarine |  |
| Barcelona | Carrer Antic de St Joan | BCN-22 | Late 17th-Early 18th | Vessel | Green |  |
| Barcelona | Carrer Antic de St Joan | BCN-23 | 18th | Vessel | Green |  |
| Barcelona | Carrer Antic de St Joan | BCN-24 | 18th | Wine glass? | Colorless |  |

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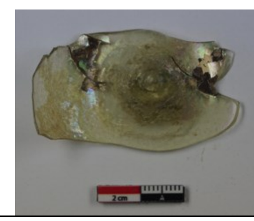
|---|---|---|---|---|---|---|
| Barcelona | Carrer Antic de St Joan | BCN-25 | 18th | Complex Vessel | Colorless |   |
| Vic | Sant Bartolomeu del Grau | SBG-1 | 18th | Phial | Green |  |
| Vic | Sant Bartolomeu del Grau | SBG-2 | 18th | Setrill spout/Figure (?) | Blue |  |
| Vic | Sant Bartolomeu del Grau | SBG-10d | 17th-18th | Vessel | Aquamarine |  |
| Vic | Sant Bartolomeu del Grau | SBG-10e | 17th-18th | Bottle/phial | Colorless |  |
| Vic | Sant Bartolomeu del Grau | SBG-10f | 17th-18th | Vessel/figure | Aquamarine |  |
| Vic | Sant Bartolomeu del Grau | SBG-20a | 17th-18th | Vessel | Blue |  |

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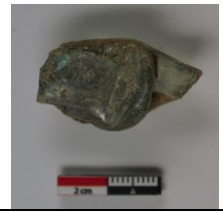
|---|---|---|---|---|---|---|
| Vic | Sant Bartolomeu del Grau | SBG-20b | 18th | Handle ? | Colorless |  |
| Vic | Sant Bartolomeu del Grau | SBG-20f | 17th-18th | Vessel | Colorless |  |
| Vic | Sant Bartolomeu del Grau | SGB-30b | 17th-18th | Bottle/phial | Green |  |
| Vic | Sant Bartolomeu del Grau | SBG-40a | 17th-18th | Bottle/phial | Green |  |
| Vic | Sant Bartolomeu del Grau | SBG-40b | 18th | Vessel | Dark blue |  |
| Vic | Sant Bartolomeu del Grau | SBG-50a | 18th | Handle | Colorless |  |
| Vic | Sant Bartolomeu del Grau | SBG-50c | 17th-18th | Bottle/phial | Green |  |
| Vic | Sant Bartolomeu del Grau | SGB-50e | 17th-18th | Phial/base | Green |  |

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|---|---|---|---|---|---|---|
| Vic | Sant Bartolomeu del Grau | SBG-50f | 17th-18th | Vessel | Green |  |

APPENDIX 2. COMPOSITIONAL DATA

Table I : EPMA-WDS compositional data for major and minor elements (in oxides wt%).

| Sample | Provenance | Color | Type | $SiO_2$ | $Na_2O$ | MgO | $Al_2O_3$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ApNi-2 | Mexico City | Green | Prod. waste | 61.06 | 16.26 | 2.97 | 4.65 | 4.67 | 6.14 | 0.15 | 0.29 | 1.37 |
| ApNi-7 | Mexico City | Green | Prod. waste | 61.81 | 15.31 | 4.15 | 3.87 | 4.01 | 6.98 | 0.18 | 0.23 | 1.24 |
| B16-11 | Mexico City | Green | Prod. waste | 61.46 | 12.83 | 4.91 | 5.12 | 4.20 | 4.92 | 0.24 | 0.42 | 1.71 |
| B16-12 | Mexico City | Green | Prod. waste | 59.76 | 16.12 | 2.72 | 6.86 | 5.57 | 2.32 | 0.14 | 0.17 | 1.02 |
| B16-13 | Mexico City | Green | Prod. waste | 56.42 | 16.35 | 6.26 | 5.51 | 3.90 | 4.94 | 0.21 | 0.06 | 1.27 |
| B16-14 | Mexico City | Green | Prod. waste | 58.16 | 15.75 | 3.44 | 5.43 | 3.56 | 6.13 | 0.21 | 0.70 | 1.63 |
| B16-15 | Mexico City | Green | Prod. waste | 62.29 | 13.46 | 4.82 | 3.42 | 5.06 | 4.53 | 0.13 | 0.29 | 1.41 |
| B16-16 | Mexico City | Green | Prod. waste | 60.83 | 13.88 | 4.70 | 3.91 | 4.74 | 4.90 | 0.18 | 0.39 | 1.54 |
| B16-17 | Mexico City | Green | Prod. waste | 65.20 | 15.17 | 3.76 | 4.16 | 4.57 | 3.35 | 0.12 | 0.05 | 0.82 |
| B16-18 | Mexico City | Green | Prod. waste | 65.94 | 10.97 | 3.94 | 3.26 | 3.68 | 6.12 | 0.18 | 0.27 | 1.47 |
| B16-19 | Mexico City | Aquamarine | Prod. waste | 63.16 | 14.22 | 5.79 | 4.79 | 5.34 | 3.34 | 0.15 | 0.04 | 0.84 |
| B16-2 | Mexico City | Aquamarine | Prod. waste | 67.44 | 13.48 | 5.99 | 2.56 | 1.79 | 4.85 | 0.08 | 0.02 | 0.76 |
| B16-20 | Mexico City | Green | Prod. waste | 60.68 | 15.75 | 4.74 | 3.72 | 4.61 | 4.28 | 0.13 | 0.09 | 1.00 |
| B16-26 | Mexico City | Green | Prod. waste | 54.01 | 17.91 | 7.57 | 3.88 | 5.18 | 6.15 | 0.12 | 0.52 | 1.12 |
| B16-29 | Mexico City | Green | Prod. waste | 53.78 | 18.89 | 6.77 | 3.46 | 4.04 | 4.40 | 0.10 | 0.03 | 0.81 |
| B16-3 | Mexico City | Green | Prod. waste | 55.01 | 17.14 | 7.62 | 5.50 | 5.38 | 4.90 | 0.18 | 0.04 | 1.12 |
| B16-30 | Mexico City | Green | Prod. waste | 60.05 | 13.96 | 4.53 | 5.69 | 4.57 | 4.51 | 0.25 | 0.46 | 1.92 |
| B16-31 | Mexico City | Aquamarine | Prod. waste | 64.25 | 16.81 | 4.31 | 4.08 | 4.38 | 3.86 | 0.13 | 0.04 | 0.88 |
| B16-32 | Mexico City | Aquamarine | Prod. waste | 68.28 | 14.29 | 4.34 | 3.92 | 2.53 | 3.17 | 0.16 | 0.02 | 0.99 |
| B16-33 | Mexico City | Green | Prod. waste | 57.71 | 15.41 | 4.67 | 7.08 | 6.69 | 3.90 | 0.22 | 0.20 | 1.64 |
| B16-34 | Mexico City | Green | Prod. waste | 55.25 | 18.57 | 5.11 | 5.62 | 5.05 | 5.43 | 0.26 | 0.37 | 1.91 |
| B16-35 | Mexico City | Green | Prod. waste | 58.21 | 10.45 | 1.15 | 17.82 | 6.32 | 0.41 | 0.64 | 0.08 | 3.45 |
| B16-36G | Mexico City | Green | Prod. waste | 60.28 | 17.83 | 3.19 | 5.63 | 3.70 | 4.79 | 0.22 | 0.48 | 1.50 |
| B16-37 | Mexico City | Aquamarine | Prod. waste | 56.99 | 19.38 | 8.12 | 3.95 | 6.06 | 2.39 | 0.12 | 0.03 | 0.88 |
| B16-38 | Mexico City | Aquamarine | Prod. waste | 58.63 | 15.70 | 3.51 | 5.69 | 5.16 | 5.61 | 0.26 | 0.16 | 1.52 |
| B16-4 | Mexico City | Aquamarine | Prod. waste | 68.14 | 15.74 | 3.99 | 2.44 | 3.59 | 3.23 | 0.07 | 0.04 | 0.65 |
| B16-49 | Mexico City | Aquamarine | Prod. waste | 64.85 | 15.00 | 3.54 | 4.48 | 5.03 | 4.55 | 0.11 | 0.03 | 0.93 |
| B16-5 | Mexico City | Aquamarine | Prod. waste | 64.86 | 15.03 | 4.86 | 4.39 | 5.10 | 3.01 | 0.10 | 0.04 | 0.73 |
| B16-6 | Mexico City | Aquamarine | Prod. waste | 67.66 | 13.98 | 2.64 | 7.57 | 3.77 | 1.73 | 0.17 | 0.03 | 1.75 |
| B16-8 | Mexico City | Green | Prod. waste | 61.41 | 14.00 | 4.22 | 6.86 | 4.36 | 4.59 | 0.30 | 0.35 | 2.00 |
| B16-9 | Mexico City | Aquamarine | Prod. waste | 66.11 | 14.10 | 4.36 | 3.50 | 4.90 | 3.65 | 0.09 | 0.04 | 0.75 |
| J70-10 | Mexico City | Aquamarine | Prod. waste | 63.40 | 12.74 | 3.91 | 3.61 | 5.59 | 6.32 | 0.23 | 0.07 | 1.27 |
| J70-24 | Mexico City | Green | Prod. waste | 60.55 | 14.28 | 4.19 | 4.85 | 5.00 | 6.11 | 0.25 | 0.05 | 1.54 |
| TM-120 | Mexico City | Green | Prod. waste | 52.84 | 18.47 | 4.59 | 6.55 | 6.04 | 6.37 | 0.32 | 0.26 | 1.69 |
| TM-180 | Mexico City | Green | Prod. waste | 52.54 | 2.63 | 3.97 | 15.49 | 1.49 | 16.84 | 0.70 | 0.09 | 4.22 |
| TM-230 | Mexico City | Aquamarine | Prod. waste | 66.38 | 15.78 | 4.24 | 4.22 | 3.33 | 3.17 | 0.14 | 0.04 | 0.98 |
| TM-231 | Mexico City | Aquamarine | Prod. waste | 66.54 | 15.59 | 4.23 | 4.18 | 2.75 | 3.37 | 0.12 | 0.05 | 1.12 |
| TM-234 | Mexico City | Green | Prod. waste | 60.24 | 14.82 | 3.19 | 4.87 | 7.01 | 5.47 | 0.23 | 0.05 | 1.41 |
| TM-235 | Mexico City | Colorless | Prod. waste | 64.44 | 15.32 | 2.93 | 3.34 | 4.89 | 4.68 | 0.09 | 0.42 | 1.14 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TM-48 | Mexico City | Green | Prod. waste | 65.20 | 17.25 | 4.22 | 3.35 | 3.41 | 2.71 | 0.14 | 0.03 | 0.87 |
| TM-49 | Mexico City | Green | Prod. waste | 65.61 | 15.59 | 4.21 | 3.01 | 4.52 | 3.36 | 0.15 | 0.01 | 0.85 |
| TM-50 | Mexico City | Green | Prod. waste | 65.02 | 14.70 | 3.48 | 3.62 | 3.64 | 5.40 | 0.18 | 0.06 | 1.07 |
| TM-53 | Mexico City | Aquamarine | Prod. waste | 70.02 | 13.29 | 4.25 | 3.89 | 1.83 | 2.58 | 0.35 | 0.07 | 0.97 |
| B16-41 | Mexico City | Purple | Rod | 58.94 | 21.66 | 1.80 | 4.15 | 1.46 | 5.26 | 0.13 | 1.31 | 1.40 |
| B16-50 | Mexico City | Green | Rod | 51.83 | 21.00 | 7.49 | 3.76 | 6.25 | 4.99 | 0.10 | 0.05 | 0.74 |
| B16-51 | Mexico City | Yellow | Rod | 55.82 | 18.50 | 6.72 | 3.32 | 5.42 | 4.63 | 0.12 | 0.41 | 1.19 |
| B16-52 | Mexico City | Green | Rod | 56.83 | 17.53 | 6.39 | 5.31 | 3.88 | 4.85 | 0.19 | 0.04 | 1.25 |
| B16-53 | Mexico City | Blue | Rod | 59.85 | 16.44 | 4.89 | 3.30 | 7.03 | 3.52 | 0.08 | 0.04 | 0.72 |
| B16-54 | Mexico City | Amber | Rod | 52.62 | 18.03 | 6.84 | 3.15 | 7.96 | 5.12 | 0.08 | 0.75 | 1.30 |
| B16-56 | Mexico City | Blue | Rod | 55.89 | 14.68 | 6.48 | 3.92 | 7.70 | 5.00 | 0.13 | 0.08 | 1.04 |
| B16-58 | Mexico City | Purple | Rod | 55.97 | 17.82 | 6.52 | 3.27 | 5.64 | 4.63 | 0.12 | 0.47 | 1.03 |
| ApNi-10 | Mexico City | Colorless | Vessel | 67.17 | 12.26 | 3.44 | 2.19 | 3.82 | 4.32 | 0.12 | 0.75 | 0.79 |
| ApNi-11 | Mexico City | Colorless | Vessel | 77.39 | 0.65 | 0.08 | 0.14 | 12.64 | 6.70 | 0.03 | 0.03 | 0.04 |
| ApNi-13 | Mexico City | Blue | Vessel | 57.71 | 16.53 | 5.36 | 4.47 | 5.36 | 4.55 | 0.15 | 0.07 | 0.98 |
| ApNi-3 | Mexico City | Colorless | Vessel | 61.45 | 14.85 | 3.63 | 2.48 | 4.91 | 6.25 | 0.06 | 0.29 | 0.60 |
| ApNi-4 | Mexico City | Blue | Vessel | 56.04 | 22.41 | 2.30 | 7.57 | 1.68 | 7.42 | 0.24 | 0.04 | 0.67 |
| ApNi-9 | Mexico City | Colorless | Vessel | 61.25 | 15.70 | 3.43 | 4.43 | 4.16 | 5.69 | 0.14 | 0.43 | 1.63 |
| B16-25 | Mexico City | Colorless | Vessel | 72.21 | 16.49 | 0.05 | 0.41 | 1.11 | 4.79 | 0.04 | 0.18 | 0.07 |
| B16-27 | Mexico City | Aquamarine | Vessel | 60.48 | 18.61 | 3.68 | 6.06 | 3.25 | 2.79 | 0.16 | 0.03 | 1.18 |
| B16-44 | Mexico City | Colorless | Vessel | 63.01 | 16.94 | 3.04 | 3.51 | 4.47 | 4.15 | 0.14 | 0.12 | 0.85 |
| B16-46 | Mexico City | Colorless | Vessel | 62.11 | 13.40 | 4.00 | 3.72 | 3.99 | 6.56 | 0.17 | 0.29 | 1.27 |
| B16-48 | Mexico City | Aquamarine | Vessel | 72.24 | 13.14 | 0.18 | 0.46 | 0.24 | 9.65 | 0.03 | 0.03 | 0.16 |
| J70-11 | Mexico City | Aquamarine | Vessel | 59.72 | 19.77 | 2.78 | 4.95 | 3.30 | 3.02 | 0.09 | 0.56 | 1.74 |
| J70-14 | Mexico City | Aquamarine | Vessel | 68.11 | 13.34 | 2.21 | 2.05 | 2.30 | 7.34 | 0.18 | 0.08 | 0.55 |
| J70-15 | Mexico City | Colorless | Vessel | 74.60 | 0.53 | 0.13 | 0.23 | 13.93 | 8.07 | 0.02 | 0.01 | 0.06 |
| J70-17 | Mexico City | Colorless | Vessel | 67.59 | 6.20 | 2.00 | 1.04 | 8.80 | 8.61 | 0.17 | 0.47 | 0.26 |
| J70-18 | Mexico City | Colorless | Vessel | 64.55 | 14.19 | 3.01 | 2.55 | 3.53 | 6.13 | 0.06 | 0.38 | 0.86 |
| J70-19 | Mexico City | Blue | Vessel | 63.71 | 17.66 | 3.18 | 2.43 | 4.58 | 4.04 | 0.10 | 0.36 | 0.93 |
| J70-20 | Mexico City | Blue | Vessel | 59.92 | 18.67 | 1.69 | 3.07 | 2.32 | 6.51 | 0.16 | 0.32 | 0.89 |
| J70-23 | Mexico City | Colorless | Vessel | 66.33 | 13.98 | 2.10 | 2.66 | 3.00 | 6.11 | 0.04 | 0.22 | 0.80 |
| J70-26 | Mexico City | Blue | Vessel | 64.23 | 16.37 | 3.10 | 2.23 | 4.39 | 4.16 | 0.11 | 0.50 | 1.10 |
| J70-27 | Mexico City | Aquamarine | Vessel | 58.09 | 14.50 | 3.53 | 9.01 | 4.83 | 4.51 | 0.08 | 0.23 | 0.80 |
| Li35-8 | Mexico City | Blue | Vessel | 56.57 | 22.55 | 2.61 | 7.29 | 2.28 | 5.78 | 0.14 | 0.27 | 1.25 |
| Li35-9 | Mexico City | Blue | Vessel | 60.81 | 21.19 | 2.11 | 5.85 | 2.31 | 5.10 | 0.11 | 0.04 | 0.83 |
| TM-135 | Mexico City | Aquamarine | Vessel | 70.59 | 12.47 | 1.64 | 1.99 | 0.71 | 9.06 | 0.07 | 0.01 | 0.15 |
| TM-142 | Mexico City | Aquamarine | Vessel | 60.40 | 20.91 | 2.90 | 3.74 | 1.93 | 4.52 | 0.07 | 0.01 | 0.66 |
| TM-150 | Mexico City | Aquamarine | Vessel | 56.94 | 16.25 | 6.56 | 4.25 | 5.03 | 4.49 | 0.06 | 0.32 | 1.01 |
| TM-152 | Mexico City | Aquamarine | Vessel | 62.01 | 14.51 | 4.27 | 3.50 | 4.08 | 4.35 | 0.17 | 0.89 | 1.70 |
| TM-232 | Mexico City | Aquamarine | Vessel | 61.83 | 14.69 | 4.01 | 4.58 | 6.34 | 4.48 | 0.18 | 0.08 | 1.12 |
| TM-300 | Mexico City | Aquamarine | Vessel | 62.64 | 17.18 | 2.95 | 4.59 | 4.46 | 4.28 | 0.12 | 0.02 | 0.81 |
| TM-303 | Mexico City | Aquamarine | Vessel | 64.52 | 12.50 | 3.78 | 2.43 | 5.21 | 5.70 | 0.16 | 0.06 | 0.89 |
| TM-310 | Mexico City | Aquamarine | Vessel | 61.73 | 14.88 | 4.74 | 3.07 | 2.87 | 5.92 | 0.11 | 0.61 | 0.94 |
| TM-32 | Mexico City | Colorless | Vessel | 72.00 | 4.76 | 0.01 | 2.46 | 0.31 | 0.13 | 0.03 | 0.01 | 0.02 |
| TM-337 | Mexico City | Colorless | Vessel | 62.95 | 13.51 | 3.66 | 0.94 | 3.40 | 9.96 | 0.04 | 0.54 | 0.39 |
| TM-360 | Mexico City | Aquamarine | Vessel | 65.16 | 17.51 | 4.36 | 3.45 | 3.42 | 2.61 | 0.10 | 0.03 | 0.86 |
| TM-38 | Mexico City | Blue | Vessel | 62.26 | 18.35 | 1.49 | 4.72 | 1.73 | 2.54 | 0.15 | 0.07 | 1.15 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HO-3 | Puebla | Aquamarine | Vessel | 66.57 | 11.54 | 1.26 | 2.02 | 0.84 | 12.29 | 0.14 | 0.78 | 0.66 |
| LS-2 | Puebla | Aquamarine | Vessel | 68.33 | 9.92 | 0.26 | 0.49 | 0.30 | 16.23 | 0.08 | 0.05 | 0.18 |
| MA-10 | Puebla | Colorless | Vessel | 72.02 | 7.90 | 0.08 | 0.51 | 0.23 | 12.52 | 0.05 | 0.18 | 0.03 |
| MA-2 | Puebla | Aquamarine | Vessel | 61.16 | 19.44 | 1.72 | 4.69 | 1.98 | 6.22 | 0.07 | 0.03 | 0.77 |
| MA-4 | Puebla | Purple | Vessel | 63.54 | 16.17 | 1.11 | 2.44 | 1.29 | 5.55 | 0.11 | 2.60 | 0.77 |
| MA-6 | Puebla | Aquamarine | Vessel | 62.10 | 18.21 | 1.85 | 3.54 | 1.84 | 6.41 | 0.13 | 0.72 | 0.76 |
| MA-7 | Puebla | Aquamarine | Vessel | 63.81 | 17.90 | 2.29 | 3.41 | 0.77 | 6.48 | 0.17 | 0.43 | 0.99 |
| MA-9 | Puebla | Colorless | Vessel | 74.55 | 0.71 | 0.07 | 0.11 | 12.18 | 8.26 | 0.01 | 0.02 | 0.06 |
| SJD-10 | Puebla | Blue | Vessel | 59.18 | 19.11 | 1.25 | 5.81 | 2.15 | 6.16 | 0.15 | 0.05 | 0.85 |
| SJD-11 | Puebla | Colorless | Vessel | 58.24 | 16.88 | 2.10 | 5.50 | 2.31 | 5.51 | 0.14 | 0.16 | 0.82 |
| SJD-12 | Puebla | Blue | Vessel | 58.52 | 18.45 | 1.13 | 5.64 | 2.17 | 5.91 | 0.11 | 0.06 | 0.82 |
| SJD-13 | Puebla | Aquamarine | Vessel | 60.32 | 18.53 | 2.21 | 3.88 | 1.76 | 7.25 | 0.09 | 0.65 | 0.75 |
| SJD-14 | Puebla | Colorless | Vessel | 58.34 | 17.38 | 2.17 | 5.48 | 2.32 | 5.52 | 0.15 | 0.16 | 0.86 |
| SJD-15 | Puebla | Colorless | Vessel | 63.10 | 7.51 | 3.84 | 2.11 | 3.22 | 11.79 | 0.11 | 0.33 | 1.10 |
| SJD-19 | Puebla | Blue | Vessel | 64.63 | 15.03 | 0.84 | 4.60 | 2.00 | 7.42 | 0.12 | 0.03 | 0.68 |
| SJD-2 | Puebla | Aquamarine | Vessel | 63.23 | 17.43 | 0.68 | 3.41 | 2.12 | 7.59 | 0.06 | 0.05 | 0.57 |
| SJD-20 | Puebla | Colorless | Vessel | 71.67 | 0.62 | 0.10 | 0.19 | 15.58 | 8.16 | 0.02 | 0.03 | 0.06 |
| SJD-21 | Puebla | Colorless | Vessel | 62.27 | 7.03 | 3.59 | 2.15 | 3.32 | 12.22 | 0.10 | 0.35 | 1.02 |
| SJD-25 | Puebla | Aquamarine | Vessel | 62.25 | 17.55 | 1.07 | 4.51 | 2.17 | 7.45 | 0.09 | 0.02 | 0.74 |
| SJD-5 | Puebla | Green | Vessel | 58.88 | 3.23 | 3.22 | 3.78 | 3.59 | 20.89 | 0.32 | 0.45 | 1.51 |
| SJD-7 | Puebla | Aquamarine | Vessel | 60.05 | 18.81 | 2.33 | 5.51 | 2.31 | 5.42 | 0.12 | 0.16 | 0.88 |
| SJD-9 | Puebla | Aquamarine | Vessel | 63.12 | 16.34 | 0.82 | 3.62 | 2.35 | 8.49 | 0.12 | 0.21 | 0.81 |
| SR-3 | Puebla | Amber | Vessel | 71.41 | 13.10 | 1.71 | 1.30 | 0.34 | 7.74 | 0.07 | 0.06 | 0.20 |
| BCN-08 | Barcelona | Colorless | Vessel | 64.61 | 14.45 | 3.73 | 1.28 | 3.81 | 8.96 | 0.08 | 0.47 | 0.81 |
| BCN-10 | Barcelona | Colorless | Vessel | 62.75 | 15.47 | 2.93 | 1.11 | 4.17 | 9.96 | 0.08 | 0.62 | 0.48 |
| BCN-11 | Barcelona | Aquamarine | Vessel | 59.36 | 17.31 | 4.27 | 2.87 | 3.48 | 9.52 | 0.16 | 0.22 | 0.89 |
| BCN-12 | Barcelona | Colorless | Vessel | 64.95 | 15.31 | 2.97 | 1.43 | 3.92 | 8.35 | 0.06 | 1.01 | 0.61 |
| BCN-13 | Barcelona | Aquamarine | Vessel | 59.85 | 17.96 | 4.37 | 3.27 | 2.54 | 8.92 | 0.17 | 0.68 | 1.03 |
| BCN-14 | Barcelona | Aquamarine | Vessel | 61.21 | 16.13 | 4.15 | 3.26 | 2.33 | 9.48 | 0.23 | 0.23 | 1.11 |
| BCN-15 | Barcelona | Green | Vessel | 60.71 | 15.79 | 4.08 | 3.23 | 2.34 | 9.33 | 0.20 | 0.23 | 1.16 |
| BCN-17 | Barcelona | Colorless | Vessel | 62.43 | 14.69 | 2.71 | 1.19 | 4.45 | 9.84 | 0.05 | 0.49 | 0.70 |
| BCN-18 | Barcelona | Colorless | Vessel | 65.70 | 16.36 | 2.31 | 2.45 | 3.07 | 4.42 | 0.12 | 0.57 | 1.01 |
| BCN-2 | Barcelona | Aquamarine | Vessel | 61.53 | 14.79 | 3.92 | 2.48 | 2.72 | 10.30 | 0.13 | 0.59 | 0.99 |
| BCN-20 | Barcelona | Aquamarine | Vessel | 59.44 | 14.89 | 4.84 | 3.11 | 2.88 | 10.21 | 0.16 | 0.24 | 1.13 |
| BCN-22 | Barcelona | Green | Vessel | 61.15 | 13.74 | 3.24 | 2.23 | 4.63 | 10.94 | 0.12 | 1.43 | 0.85 |
| BCN-23 | Barcelona | Green | Vessel | 61.70 | 16.40 | 4.29 | 3.25 | 2.31 | 9.47 | 0.22 | 0.29 | 1.10 |
| BCN-24 | Barcelona | Colorless | Vessel | 62.95 | 16.12 | 4.15 | 0.96 | 4.34 | 9.17 | 0.05 | 0.37 | 0.38 |
| BCN-25 | Barcelona | Colorless | Vessel | 64.58 | 16.84 | 4.25 | 1.14 | 3.58 | 7.72 | 0.08 | 0.25 | 0.54 |
| BCN-3 | Barcelona | Colorless | Vessel | 60.92 | 14.55 | 4.17 | 3.69 | 1.62 | 9.68 | 0.24 | 0.53 | 1.32 |
| BCN-4 | Barcelona | Aquamarine | Vessel | 65.15 | 12.80 | 3.32 | 1.96 | 3.50 | 8.52 | 0.08 | 0.99 | 0.77 |
| BCN-5 | Barcelona | Colorless | Vessel | 63.10 | 16.70 | 3.86 | 2.30 | 2.17 | 7.14 | 0.10 | 0.35 | 0.73 |
| BCN-6 | Barcelona | Aquamarine | Vessel | 60.33 | 14.82 | 4.49 | 3.71 | 2.23 | 10.16 | 0.22 | 0.23 | 1.32 |
| BCN-7 | Barcelona | Colorless | Vessel | 65.41 | 17.65 | 3.14 | 1.28 | 2.64 | 6.30 | 0.05 | 0.42 | 0.48 |
| SBG-1 | Vic | Green | Vessel | 61.70 | 18.21 | 3.77 | 4.68 | 2.21 | 8.33 | 0.23 | 0.21 | 1.35 |
| SBG-10d | Vic | Aquamarine | Vessel | 64.11 | 16.64 | 2.83 | 3.55 | 3.36 | 8.70 | 0.21 | 0.25 | 0.75 |
| SBG-10e | Vic | Colorless | Vessel | 65.51 | 17.34 | 3.45 | 2.12 | 2.79 | 8.40 | 0.11 | 0.48 | 0.90 |
| SBG-10f | Vic | Aquamarine | Vessel | 61.66 | 17.57 | 3.95 | 4.92 | 2.53 | 8.06 | 0.21 | 0.18 | 1.36 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SBG-2 | Vic | Blue | Vessel | 66.73 | 16.10 | 2.70 | 2.06 | 3.66 | 7.50 | 0.10 | 0.51 | 0.82 |
| SBG-20a | Vic | Blue | Vessel | 68.52 | 16.89 | 1.90 | 1.10 | 2.83 | 7.96 | 0.02 | 0.41 | 0.43 |
| SBG-20b | Vic | Colorless | Vessel | 67.25 | 16.46 | 3.34 | 2.03 | 3.30 | 6.65 | 0.04 | 0.34 | 0.69 |
| SBG-20f | Vic | Aquamarine | Vessel | 61.57 | 15.70 | 4.38 | 3.58 | 1.94 | 9.47 | 0.17 | 0.13 | 1.28 |
| ApNi-8 | Imported | Red | Vessel | 58.58 | 19.02 | 1.35 | 5.33 | 1.44 | 3.41 | 0.17 | 0.05 | 6.29 |
| J70-13 | Imported | Colorless | Vessel | 65.90 | 13.12 | 3.64 | 0.96 | 2.14 | 10.24 | 0.06 | 0.29 | 0.35 |
| J70-2 | Imported | Green | Vessel | 57.95 | 1.81 | 2.23 | 3.80 | 1.26 | 25.90 | 0.24 | 0.53 | 1.94 |
| J70-32 | Imported | Green | Vessel | 62.23 | 2.72 | 2.88 | 3.92 | 2.28 | 21.60 | 0.20 | 0.03 | 1.14 |
| J70-35 | Imported | Green | Vessel | 56.47 | 1.92 | 3.82 | 4.69 | 2.04 | 24.79 | 0.29 | 0.11 | 2.17 |
| J70-40 | Imported | Green | Vessel | 59.78 | 1.67 | 4.83 | 4.60 | 2.04 | 21.11 | 0.27 | 0.16 | 2.03 |
| J70-44 | Imported | Green | Vessel | 55.90 | 2.30 | 3.59 | 4.45 | 2.49 | 24.57 | 0.19 | 0.28 | 1.37 |
| J70-46 | Imported | Green | Vessel | 56.47 | 2.19 | 3.63 | 4.02 | 2.56 | 24.60 | 0.21 | 0.34 | 1.23 |
| Li35-3 | Imported | Green | Vessel | 57.80 | 2.05 | 1.51 | 6.93 | 1.25 | 25.56 | 0.23 | 0.01 | 1.43 |
| Li35-4 | Imported | Green | Vessel | 60.02 | 1.59 | 1.04 | 6.73 | 1.93 | 24.61 | 0.24 | 0.03 | 1.37 |
| Li35-5 | Imported | Green | Vessel | 56.37 | 2.14 | 3.57 | 4.17 | 2.49 | 24.52 | 0.19 | 0.31 | 1.22 |
| Li35-7 | Imported | Aquamarine | Vessel | 64.77 | 14.51 | 7.12 | 0.33 | 0.13 | 9.75 | 0.13 | 0.02 | 0.20 |
| MA-8 | Imported | Aquamarine | Vessel | 74.94 | 13.09 | 0.15 | 0.67 | 0.12 | 8.09 | 0.01 | 0.02 | 0.06 |

Table II. LA-ICP-MS compositional data for major and minor elements (in oxides wt%).

| Sample | Provenance | Color | Type | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ApNi-2 | Mexico City | Green | Prod. waste | 16.45 | 2.60 | 4.89 | 61.06 | 1.12 | 4.67 | 6.45 | 0.16 | 0.29 | 1.22 |
| ApNi-7 | Mexico City | Green | Prod. waste | 15.66 | 3.66 | 4.18 | 61.81 | 1.00 | 4.42 | 7.54 | 0.15 | 0.25 | 1.16 |
| B16-11 | Mexico City | Green | Prod. waste | 14.86 | 4.27 | 5.92 | 61.46 | 1.06 | 4.16 | 5.23 | 0.24 | 0.40 | 1.51 |
| B16-12 | Mexico City | Green | Prod. waste | 18.46 | 2.41 | 8.76 | 59.76 | 0.29 | 5.49 | 2.47 | 0.12 | 0.16 | 0.85 |
| B16-13 | Mexico City | Green | Prod. waste | 19.66 | 5.67 | 6.14 | 56.42 | 1.34 | 3.93 | 5.40 | 0.21 | 0.07 | 1.11 |
| B16-14 | Mexico City | Green | Prod. waste | 19.73 | 3.13 | 6.18 | 58.16 | 1.17 | 3.73 | 6.93 | 0.24 | 0.69 | 1.40 |
| B16-15 | Mexico City | Green | Prod. waste | 16.97 | 4.54 | 4.03 | 62.29 | 1.20 | 5.00 | 5.13 | 0.15 | 0.34 | 1.26 |
| B16-16 | Mexico City | Green | Prod. waste | 17.15 | 4.45 | 4.53 | 60.83 | 1.26 | 4.60 | 5.52 | 0.19 | 0.41 | 1.39 |
| B16-17 | Mexico City | Green | Prod. waste | 15.03 | 3.20 | 4.02 | 65.20 | 1.14 | 4.59 | 3.47 | 0.10 | 0.05 | 0.74 |
| B16-18 | Mexico City | Green | Prod. waste | 13.26 | 3.83 | 3.94 | 65.94 | 0.95 | 3.68 | 7.11 | 0.22 | 0.29 | 1.37 |
| B16-19 | Mexico City | Aquamarine | Prod. waste | 13.41 | 5.69 | 4.41 | 63.16 | 1.22 | 5.14 | 4.88 | 0.12 | 0.05 | 0.81 |
| B16-2 | Mexico City | Aquamarine | Prod. waste | 14.22 | 5.07 | 3.04 | 67.44 | 1.76 | 2.11 | 4.86 | 0.10 | 0.03 | 0.74 |
| B16-20 | Mexico City | Green | Prod. waste | 19.27 | 4.26 | 4.15 | 60.68 | 1.56 | 4.66 | 5.17 | 0.14 | 0.09 | 0.92 |
| B16-26 | Mexico City | Green | Prod. waste | 20.35 | 6.86 | 4.48 | 54.01 | 2.03 | 4.95 | 6.89 | 0.12 | 0.55 | 1.10 |
| B16-29 | Mexico City | Green | Prod. waste | 21.66 | 5.94 | 3.80 | 53.78 | 1.40 | 4.09 | 5.07 | 0.09 | 0.05 | 0.73 |
| B16-3 | Mexico City | Green | Prod. waste | 15.43 | 7.37 | 4.84 | 55.01 | 1.90 | 4.93 | 7.84 | 0.15 | 0.05 | 0.97 |
| B16-30 | Mexico City | Green | Prod. waste | 16.20 | 4.29 | 5.98 | 60.05 | 1.12 | 4.21 | 5.11 | 0.22 | 0.48 | 1.58 |
| B16-31 | Mexico City | Aquamarine | Prod. waste | 18.28 | 3.73 | 4.12 | 64.25 | 0.70 | 4.54 | 3.98 | 0.12 | 0.03 | 0.82 |
| B16-32 | Mexico City | Aquamarine | Prod. waste | 14.96 | 3.78 | 4.05 | 68.28 | 1.31 | 2.65 | 3.21 | 0.14 | 0.04 | 0.89 |
| B16-33 | Mexico City | Green | Prod. waste | 15.17 | 4.38 | 6.91 | 57.71 | 1.31 | 5.86 | 4.41 | 0.23 | 0.23 | 1.33 |
| B16-34 | Mexico City | Green | Prod. waste | 18.93 | 3.98 | 5.54 | 55.25 | 1.05 | 4.60 | 8.13 | 0.25 | 0.34 | 1.49 |
| B16-36G | Mexico City | Green | Prod. waste | 18.76 | 2.78 | 5.99 | 59.94 | 0.73 | 3.75 | 4.96 | 0.24 | 0.44 | 1.33 |
| B16-36P | Mexico City | Purple | Prod. waste | 18.23 | 2.71 | 5.83 | 59.21 | 0.80 | 3.96 | 4.96 | 0.22 | 0.50 | 1.32 |
| B16-37 | Mexico City | Aquamarine | Prod. waste | 17.05 | 6.07 | 4.34 | 56.99 | 1.00 | 5.00 | 4.21 | 0.11 | 0.03 | 0.82 |
| B16-38 | Mexico City | Aquamarine | Prod. waste | 16.58 | 3.12 | 6.30 | 58.63 | 1.47 | 5.03 | 5.67 | 0.26 | 0.16 | 1.39 |
| B16-4 | Mexico City | Aquamarine | Prod. waste | 16.97 | 3.40 | 2.52 | 68.14 | 1.11 | 3.90 | 3.28 | 0.08 | 0.03 | 0.64 |
| B16-49 | Mexico City | Aquamarine | Prod. waste | 16.03 | 3.18 | 4.73 | 64.85 | 0.97 | 4.94 | 4.87 | 0.12 | 0.04 | 0.85 |
| B16-5 | Mexico City | Aquamarine | Prod. waste | 15.45 | 4.19 | 4.57 | 64.86 | 0.89 | 4.98 | 3.15 | 0.10 | 0.04 | 0.69 |
| B16-6 | Mexico City | Aquamarine | Prod. waste | 14.76 | 2.25 | 8.23 | 67.66 | 0.64 | 4.03 | 1.63 | 0.16 | 0.02 | 1.56 |
| B16-8 | Mexico City | Green | Prod. waste | 14.14 | 3.91 | 6.47 | 61.41 | 1.00 | 4.36 | 4.99 | 0.25 | 0.37 | 1.59 |
| B16-9 | Mexico City | Aquamarine | Prod. waste | 14.87 | 3.77 | 3.60 | 66.11 | 1.01 | 4.88 | 3.61 | 0.09 | 0.04 | 0.70 |
| J70-10 | Mexico City | Aquamarine | Prod. waste | 13.55 | 3.60 | 3.86 | 63.40 | 1.68 | 5.23 | 6.60 | 0.21 | 0.09 | 1.13 |
| J70-24 | Mexico City | Green | Prod. waste | 14.07 | 3.64 | 5.05 | 60.55 | 1.51 | 4.69 | 6.44 | 0.24 | 0.06 | 1.35 |
| TM-120 | Mexico City | Green | Prod. waste | 18.53 | 3.99 | 6.86 | 52.84 | 1.89 | 5.45 | 6.71 | 0.28 | 0.26 | 1.46 |
| TM-230 | Mexico City | Aquamarine | Prod. waste | 17.01 | 3.60 | 4.18 | 66.38 | 0.90 | 3.65 | 3.33 | 0.13 | 0.04 | 0.92 |
| TM-231 | Mexico City | Aquamarine | Prod. waste | 16.47 | 3.64 | 4.19 | 66.54 | 0.97 | 2.87 | 3.43 | 0.15 | 0.04 | 0.98 |
| TM-234 | Mexico City | Green | Prod. waste | 14.74 | 2.74 | 5.14 | 60.24 | 1.59 | 6.32 | 5.78 | 0.20 | 0.06 | 1.16 |
| TM-235 | Mexico City | Colorless | Prod. waste | 15.20 | 2.56 | 3.56 | 64.44 | 0.75 | 4.09 | 4.94 | 0.09 | 0.37 | 0.95 |
| TM-48 | Mexico City | Green | Prod. waste | 17.66 | 3.40 | 3.43 | 65.20 | 1.27 | 3.76 | 2.81 | 0.10 | 0.03 | 0.75 |
| TM-49 | Mexico City | Green | Prod. waste | 15.61 | 3.54 | 3.04 | 65.61 | 1.15 | 4.65 | 3.35 | 0.09 | 0.03 | 0.70 |
| TM-50 | Mexico City | Green | Prod. waste | 14.30 | 2.93 | 3.63 | 65.02 | 0.77 | 3.79 | 5.49 | 0.14 | 0.06 | 0.90 |
| TM-53 | Mexico City | Aquamarine | Prod. waste | 14.13 | 3.55 | 3.97 | 70.02 | 1.36 | 1.93 | 2.80 | 0.37 | 0.04 | 0.91 |
| B16-41 | Mexico City | Purple | Rod | 26.30 | 1.49 | 4.36 | 58.94 | 0.23 | 1.53 | 5.74 | 0.14 | 1.18 | 1.23 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B16-50 | Mexico City | Green | Rod | 22.90 | 6.53 | 4.01 | 51.83 | 1.79 | 5.65 | 5.56 | 0.10 | 0.06 | 0.69 |
| B16-51 | Mexico City | Yellow | Rod | 20.99 | 6.13 | 3.64 | 55.82 | 1.64 | 5.14 | 5.23 | 0.11 | 0.42 | 1.07 |
| B16-52 | Mexico City | Green | Rod | 20.10 | 5.80 | 6.08 | 56.83 | 1.46 | 3.98 | 5.32 | 0.18 | 0.05 | 1.06 |
| B16-53 | Mexico City | Blue | Rod | 18.45 | 4.65 | 3.99 | 59.85 | 1.37 | 6.57 | 4.17 | 0.08 | 0.04 | 0.70 |
| B16-54 | Mexico City | Amber | Rod | 19.39 | 5.93 | 3.48 | 52.62 | 1.73 | 7.14 | 5.81 | 0.08 | 0.73 | 1.12 |
| B16-56 | Mexico City | Blue | Rod | 17.43 | 6.24 | 4.44 | 55.89 | 2.09 | 7.33 | 5.94 | 0.13 | 0.05 | 0.90 |
| B16-58 | Mexico City | Purple | Rod | 20.66 | 6.03 | 3.64 | 55.98 | 1.64 | 5.30 | 5.47 | 0.11 | 0.51 | 0.93 |
| ApNi-10 | Mexico City | Colorless | Vessel | 14.72 | 3.07 | 2.31 | 67.17 | 0.94 | 4.06 | 4.68 | 0.11 | 0.75 | 0.74 |
| ApNi-11 | Mexico City | Colorless | Vessel | 0.85 | 0.11 | 0.15 | 77.39 | 0.23 | 11.63 | 6.29 | 0.01 | 0.04 | 0.05 |
| ApNi-13 | Mexico City | Blue | Vessel | 16.09 | 4.51 | 4.62 | 57.71 | 1.08 | 4.59 | 4.59 | 0.15 | 0.07 | 0.82 |
| ApNi-3 | Mexico City | Colorless | Vessel | 17.32 | 3.31 | 2.63 | 61.45 | 1.15 | 4.95 | 6.76 | 0.08 | 0.30 | 0.57 |
| ApNi-4 | Mexico City | Blue | Vessel | 21.63 | 1.77 | 7.20 | 56.04 | 0.13 | 1.56 | 7.33 | 0.22 | 0.05 | 0.57 |
| ApNi-9 | Mexico City | Colorless | Vessel | 15.46 | 2.96 | 4.66 | 61.25 | 0.94 | 3.79 | 5.79 | 0.15 | 0.44 | 1.35 |
| B16-25 | Mexico City | Colorless | Vessel | 19.49 | 0.04 | 0.39 | 72.22 | 0.01 | 1.14 | 4.71 | 0.02 | 0.16 | 0.05 |
| B16-27 | Mexico City | Aquamarine | Vessel | 22.57 | 2.93 | 6.35 | 60.48 | 0.34 | 3.39 | 3.20 | 0.16 | 0.03 | 1.00 |
| B16-44 | Mexico City | Colorless | Vessel | 19.04 | 2.66 | 3.54 | 63.01 | 0.86 | 4.70 | 4.53 | 0.11 | 0.15 | 0.77 |
| B16-46 | Mexico City | Colorless | Vessel | 15.42 | 3.69 | 3.87 | 62.11 | 1.16 | 4.34 | 6.94 | 0.14 | 0.28 | 1.08 |
| B16-48 | Mexico City | Aquamarine | Vessel | 15.57 | 0.14 | 0.48 | 72.24 | 0.02 | 0.25 | 10.77 | 0.03 | 0.02 | 0.13 |
| J70-11 | Mexico City | Aquamarine | Vessel | 22.73 | 2.15 | 5.01 | 59.72 | 0.57 | 3.31 | 3.48 | 0.12 | 0.57 | 1.49 |
| J70-14 | Mexico City | Aquamarine | Vessel | 15.09 | 1.77 | 2.18 | 68.11 | 0.38 | 2.44 | 8.27 | 0.17 | 0.09 | 0.52 |
| J70-15 | Mexico City | Colorless | Vessel | 0.61 | 0.12 | 0.26 | 74.61 | 0.11 | 13.14 | 8.25 | 0.01 | 0.01 | 0.07 |
| J70-18 | Mexico City | Colorless | Vessel | 16.40 | 2.68 | 2.65 | 64.55 | 0.59 | 3.80 | 6.79 | 0.08 | 0.39 | 0.77 |
| J70-19 | Mexico City | Blue | Vessel | 17.62 | 2.64 | 2.56 | 63.72 | 0.81 | 4.09 | 4.20 | 0.07 | 0.34 | 0.78 |
| J70-20 | Mexico City | Blue | Vessel | 19.48 | 1.41 | 3.19 | 59.92 | 0.35 | 2.18 | 6.65 | 0.11 | 0.32 | 0.77 |
| J70-21 | Mexico City | Aquamarine | Vessel | 24.33 | 1.18 | 5.99 | 68.45 | 0.16 | 2.24 | 5.00 | 0.18 | 0.12 | 1.05 |
| J70-23 | Mexico City | Colorless | Vessel | 16.50 | 1.82 | 2.85 | 66.33 | 0.36 | 3.13 | 6.75 | 0.07 | 0.22 | 0.69 |
| J70-26 | Mexico City | Blue | Vessel | 16.20 | 2.66 | 2.36 | 64.23 | 0.79 | 4.08 | 4.42 | 0.08 | 0.49 | 0.96 |
| Li35-8 | Mexico City | Blue | Vessel | 22.45 | 2.11 | 7.22 | 56.57 | 0.14 | 2.12 | 5.81 | 0.14 | 0.27 | 1.06 |
| Li35-9 | Mexico City | Blue | Vessel | 21.14 | 1.71 | 5.79 | 60.81 | 0.12 | 2.20 | 5.13 | 0.12 | 0.03 | 0.71 |
| TM-135 | Mexico City | Aquamarine | Vessel | 14.41 | 1.18 | 2.04 | 70.59 | 0.02 | 0.74 | 9.93 | 0.06 | 0.03 | 0.18 |
| TM-142 | Mexico City | Aquamarine | Vessel | 25.41 | 2.24 | 3.79 | 60.40 | 0.13 | 2.12 | 5.23 | 0.10 | 0.02 | 0.58 |
| TM-150 | Mexico City | Aquamarine | Vessel | 19.41 | 5.73 | 4.73 | 56.94 | 1.50 | 4.75 | 5.31 | 0.11 | 0.35 | 0.89 |
| TM-152 | Mexico City | Aquamarine | Vessel | 16.92 | 3.74 | 3.81 | 62.01 | 1.00 | 3.84 | 5.29 | 0.16 | 0.82 | 1.50 |
| TM-232 | Mexico City | Aquamarine | Vessel | 14.57 | 3.56 | 5.05 | 61.83 | 1.27 | 5.27 | 4.92 | 0.17 | 0.07 | 0.97 |
| TM-300 | Mexico City | Aquamarine | Vessel | 18.69 | 2.43 | 4.81 | 62.64 | 0.59 | 4.18 | 4.90 | 0.13 | 0.02 | 0.70 |
| TM-303 | Mexico City | Aquamarine | Vessel | 14.58 | 3.22 | 2.70 | 64.52 | 1.17 | 4.77 | 6.54 | 0.15 | 0.07 | 0.77 |
| TM-310 | Mexico City | Aquamarine | Vessel | 17.40 | 4.08 | 3.35 | 61.74 | 1.11 | 3.00 | 6.83 | 0.13 | 0.63 | 0.85 |
| TM-337 | Mexico City | Colorless | Vessel | 14.45 | 3.14 | 0.95 | 62.95 | 0.26 | 3.60 | 10.19 | 0.05 | 0.54 | 0.35 |
| TM-360 | Mexico City | Aquamarine | Vessel | 17.29 | 3.49 | 3.56 | 65.16 | 1.33 | 3.17 | 2.79 | 0.12 | 0.03 | 0.71 |
| TM-38 | Mexico City | Blue | Vessel | 22.92 | 1.11 | 4.77 | 64.16 | 0.22 | 1.69 | 2.71 | 0.15 | 0.08 | 1.01 |
| HO-3 | Puebla | Aquamarine | Vessel | 12.97 | 1.05 | 2.02 | 66.57 | 0.06 | 0.86 | 12.66 | 0.12 | 0.75 | 0.61 |
| MA-10 | Puebla | Colorless | Vessel | 10.72 | 0.06 | 0.52 | 72.02 | 0.01 | 0.23 | 12.65 | 0.05 | 0.17 | 0.05 |
| MA-2 | Puebla | Aquamarine | Vessel | 20.91 | 1.32 | 4.50 | 61.16 | 0.13 | 2.09 | 6.51 | 0.10 | 0.04 | 0.66 |
| MA-4 | Puebla | Purple | Vessel | 20.29 | 0.96 | 2.72 | 63.54 | 0.11 | 1.41 | 6.46 | 0.09 | 2.42 | 0.68 |
| MA-6 | Puebla | Aquamarine | Vessel | 20.82 | 1.42 | 3.48 | 62.10 | 0.16 | 1.85 | 6.61 | 0.12 | 0.70 | 0.64 |
| MA-7 | Puebla | Aquamarine | Vessel | 19.63 | 1.74 | 3.31 | 63.81 | 0.12 | 0.77 | 6.58 | 0.14 | 0.41 | 0.80 |
| MA-9 | Puebla | Colorless | Vessel | 0.78 | 0.11 | 0.12 | 74.55 | 0.11 | 11.16 | 8.01 | 0.01 | 0.01 | 0.05 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SJD-10 | Puebla | Blue | Vessel | 23.60 | 0.97 | 5.94 | 59.18 | 0.08 | 2.41 | 7.05 | 0.12 | 0.06 | 0.76 |
| SJD-11 | Puebla | Colorless | Vessel | 22.83 | 1.92 | 5.62 | 58.24 | 0.14 | 2.52 | 5.97 | 0.12 | 0.15 | 0.76 |
| SJD-12 | Puebla | Blue | Vessel | 23.64 | 0.98 | 5.96 | 58.52 | 0.09 | 2.33 | 6.73 | 0.11 | 0.05 | 0.73 |
| SJD-13 | Puebla | Aquamarine | Vessel | 20.52 | 1.73 | 3.81 | 60.32 | 0.14 | 1.84 | 7.61 | 0.10 | 0.59 | 0.62 |
| SJD-14 | Puebla | Colorless | Vessel | 22.44 | 1.88 | 5.55 | 58.34 | 0.12 | 2.48 | 5.78 | 0.11 | 0.15 | 0.77 |
| SJD-15 | Puebla | Colorless | Vessel | 9.40 | 3.78 | 2.25 | 63.10 | 1.36 | 3.38 | 12.74 | 0.11 | 0.34 | 0.92 |
| SJD-19 | Puebla | Blue | Vessel | 18.09 | 0.72 | 4.83 | 64.63 | 0.08 | 2.15 | 8.32 | 0.09 | 0.04 | 0.63 |
| SJD-2 | Puebla | Aquamarine | Vessel | 20.41 | 0.51 | 3.00 | 63.23 | 0.09 | 2.22 | 7.76 | 0.06 | 0.08 | 0.55 |
| SJD-20 | Puebla | Colorless | Vessel | 0.85 | 0.09 | 0.19 | 71.67 | 0.12 | 14.16 | 8.15 | 0.01 | 0.01 | 0.06 |
| SJD-21 | Puebla | Colorless | Vessel | 9.34 | 3.74 | 2.28 | 62.27 | 1.43 | 3.60 | 13.46 | 0.12 | 0.37 | 0.91 |
| SJD-25 | Puebla | Aquamarine | Vessel | 19.86 | 0.85 | 4.48 | 62.25 | 0.08 | 2.31 | 7.85 | 0.08 | 0.04 | 0.66 |
| SJD-5 | Puebla | Green | Vessel | 3.72 | 2.94 | 4.00 | 58.88 | 1.31 | 3.47 | 23.85 | 0.32 | 0.48 | 1.32 |
| SJD-7 | Puebla | Aquamarine | Vessel | 21.72 | 1.83 | 5.31 | 60.05 | 0.12 | 2.36 | 5.55 | 0.11 | 0.15 | 0.72 |
| SJD-9 | Puebla | Aquamarine | Vessel | 18.69 | 0.67 | 3.77 | 63.13 | 0.08 | 2.48 | 8.83 | 0.07 | 0.21 | 0.69 |
| SR-3 | Puebla | Amber | Vessel | 15.77 | 1.48 | 1.24 | 71.41 | 0.02 | 0.35 | 8.11 | 0.06 | 0.05 | 0.20 |
| BCN-08 | Barcelona | Colorless | Vessel | 15.13 | 3.46 | 1.50 | 64.61 | 0.27 | 4.51 | 10.25 | 0.10 | 0.48 | 0.76 |
| BCN-10 | Barcelona | Colorless | Vessel | 15.49 | 2.60 | 1.19 | 62.75 | 0.56 | 4.78 | 10.95 | 0.07 | 0.64 | 0.45 |
| BCN-11 | Barcelona | Aquamarine | Vessel | 17.65 | 3.70 | 3.16 | 59.36 | 0.64 | 3.95 | 10.44 | 0.16 | 0.21 | 0.80 |
| BCN-12 | Barcelona | Colorless | Vessel | 15.70 | 2.64 | 1.56 | 64.95 | 0.40 | 4.60 | 9.28 | 0.08 | 0.94 | 0.58 |
| BCN-13 | Barcelona | Aquamarine | Vessel | 18.69 | 3.86 | 3.58 | 59.85 | 0.58 | 3.02 | 9.95 | 0.17 | 0.63 | 0.92 |
| BCN-14 | Barcelona | Aquamarine | Vessel | 15.72 | 3.69 | 3.56 | 61.21 | 0.54 | 2.55 | 10.63 | 0.24 | 0.24 | 0.99 |
| BCN-15 | Barcelona | Green | Vessel | 15.34 | 3.60 | 3.49 | 60.71 | 0.54 | 2.55 | 10.53 | 0.23 | 0.24 | 0.96 |
| BCN-17 | Barcelona | Colorless | Vessel | 13.84 | 2.45 | 1.28 | 62.43 | 0.42 | 4.21 | 11.03 | 0.07 | 0.50 | 0.64 |
| BCN-18 | Barcelona | Colorless | Vessel | 15.99 | 1.86 | 2.51 | 65.70 | 0.48 | 3.21 | 4.71 | 0.13 | 0.50 | 0.83 |
| BCN-2 | Barcelona | Aquamarine | Vessel | 15.12 | 3.50 | 2.72 | 61.53 | 0.60 | 3.20 | 10.75 | 0.14 | 0.51 | 0.88 |
| BCN-20 | Barcelona | Aquamarine | Vessel | 14.40 | 4.36 | 3.26 | 59.44 | 0.77 | 3.03 | 11.32 | 0.17 | 0.24 | 0.99 |
| BCN-22 | Barcelona | Green | Vessel | 14.86 | 3.21 | 2.58 | 61.15 | 0.51 | 5.71 | 12.60 | 0.13 | 1.29 | 0.81 |
| BCN-23 | Barcelona | Green | Vessel | 17.45 | 3.92 | 3.62 | 61.70 | 0.74 | 2.98 | 10.94 | 0.23 | 0.27 | 1.02 |
| BCN-24 | Barcelona | Colorless | Vessel | 16.86 | 3.88 | 1.04 | 62.95 | 0.46 | 5.35 | 10.95 | 0.06 | 0.37 | 0.42 |
| BCN-25 | Barcelona | Colorless | Vessel | 17.51 | 3.94 | 1.24 | 64.58 | 0.32 | 4.37 | 8.86 | 0.07 | 0.24 | 0.51 |
| BCN-3 | Barcelona | Colorless | Vessel | 14.87 | 3.83 | 3.99 | 60.92 | 0.57 | 1.85 | 10.22 | 0.21 | 0.58 | 1.26 |
| BCN-4 | Barcelona | Aquamarine | Vessel | 13.18 | 3.06 | 2.16 | 65.15 | 0.34 | 4.01 | 9.49 | 0.11 | 0.90 | 0.72 |
| BCN-5 | Barcelona | Colorless | Vessel | 17.30 | 3.47 | 2.43 | 63.10 | 0.42 | 2.42 | 7.65 | 0.10 | 0.39 | 0.66 |
| BCN-6 | Barcelona | Aquamarine | Vessel | 15.42 | 4.07 | 3.98 | 60.33 | 0.67 | 2.62 | 10.97 | 0.22 | 0.22 | 1.23 |
| BCN-7 | Barcelona | Colorless | Vessel | 18.70 | 2.66 | 1.36 | 65.41 | 0.37 | 3.12 | 6.74 | 0.06 | 0.44 | 0.50 |
| SBG-1 | Vic | Green | Vessel | 18.12 | 3.47 | 4.89 | 61.70 | 0.52 | 2.60 | 9.28 | 0.23 | 0.20 | 1.15 |
| SBG-10d | Vic | Aquamarine | Vessel | 16.31 | 2.58 | 3.81 | 64.11 | 0.59 | 3.98 | 9.76 | 0.20 | 0.24 | 0.70 |
| SBG-10e | Vic | Colorless | Vessel | 17.82 | 3.25 | 2.28 | 65.51 | 0.61 | 3.31 | 9.84 | 0.12 | 0.53 | 0.74 |
| SBG-10f | Vic | Aquamarine | Vessel | 17.69 | 3.57 | 5.26 | 61.66 | 0.54 | 2.98 | 9.27 | 0.23 | 0.20 | 1.20 |
| SBG-2 | Vic | Blue | Vessel | 16.37 | 2.45 | 2.20 | 66.73 | 0.57 | 4.24 | 8.43 | 0.11 | 0.52 | 0.76 |
| SBG-20a | Vic | Blue | Vessel | 17.17 | 1.82 | 1.17 | 68.52 | 0.55 | 3.42 | 8.89 | 0.05 | 0.43 | 0.40 |
| SBG-20b | Vic | Colorless | Vessel | 16.88 | 3.15 | 2.10 | 67.25 | 0.40 | 3.99 | 7.90 | 0.09 | 0.35 | 0.61 |
| SBG-20f | Vic | Aquamarine | Vessel | 16.70 | 4.09 | 3.83 | 61.57 | 0.61 | 2.39 | 10.55 | 0.22 | 0.14 | 1.17 |
| ApNi-8 | Imported | Red | Vessel | 22.42 | 1.03 | 5.39 | 58.58 | 0.18 | 1.87 | 3.54 | 0.17 | 0.06 | 4.90 |
| J70-13 | Imported | Colorless | Vessel | 14.67 | 3.42 | 0.99 | 65.90 | 0.23 | 3.59 | 11.71 | 0.25 | 0.94 | 1.14 |
| J70-2 | Imported | Green | Vessel | 2.36 | 1.95 | 3.88 | 57.95 | 1.48 | 2.90 | 11.47 | 0.05 | 0.29 | 0.32 |
| J70-32 | Imported | Green | Vessel | 3.03 | 2.63 | 3.94 | 62.23 | 0.46 | 1.64 | 25.92 | 0.21 | 0.52 | 1.67 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J70-35 | Imported | Green | Vessel | 2.51 | 3.45 | 4.87 | 56.47 | 0.50 | 2.92 | 22.26 | 0.18 | 0.03 | 0.97 |
| J70-40 | Imported | Green | Vessel | 2.25 | 4.39 | 4.76 | 59.78 | 0.62 | 2.80 | 26.05 | 0.24 | 0.10 | 1.93 |
| J70-44 | Imported | Green | Vessel | 2.74 | 3.29 | 4.62 | 55.90 | 2.13 | 2.75 | 22.15 | 0.25 | 0.16 | 1.78 |
| J70-46 | Imported | Green | Vessel | 2.68 | 3.37 | 4.32 | 56.47 | 2.32 | 0.16 | 9.57 | 0.14 | 0.01 | 0.18 |
| Li35-3 | Imported | Green | Vessel | 2.54 | 1.36 | 6.87 | 57.80 | 0.05 | 3.34 | 25.75 | 0.21 | 0.29 | 1.21 |
| Li35-4 | Imported | Green | Vessel | 2.07 | 0.93 | 6.71 | 60.02 | 0.04 | 1.60 | 26.53 | 0.20 | 0.03 | 1.19 |
| Li35-5 | Imported | Green | Vessel | 2.66 | 3.28 | 4.20 | 56.37 | 2.21 | 2.50 | 24.85 | 0.21 | 0.02 | 1.19 |
| Li35-6 | Imported | Green | Vessel | 4.84 | 4.98 | 5.04 | 59.28 | 0.25 | 3.32 | 25.03 | 0.18 | 0.29 | 1.04 |
| Li35-7 | Imported | Aquamarine | Vessel | 15.16 | 5.58 | 0.33 | 64.77 | 0.01 | 3.44 | 25.75 | 0.17 | 0.32 | 1.04 |
| MA-8 | Imported | Aquamarine | Vessel | 15.56 | 0.10 | 0.66 | 74.94 | 0.02 | 0.13 | 8.42 | 0.03 | 0.01 | 0.08 |

Table III. LA-ICP-MS compositional data for trace elements and REEs (in ppm).

| Sample | Provenance | Color | Type | Li | B | V | Cr | Co | Ni | Cu | Zn | As | Rb | Sr | Y | Zr | Nb | Mo | Ag | Sn | Sb | Cs | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ApNi-2 | Mex. City | Green | PW | 163 | 61 | 21 | 14 | 5 | 7 | 13 | 90 | 13 | 40 | 505 | 4.7 | 39 | 1.5 | 0.2 | 8 | 0.0 | 17 | 0.95 | 280 |
| ApNi-7 | Mex. City | Green | PW | 145 | 6 | 21 | 18 | 5 | 7 | 29 | 80 | 16 | 32 | 663 | 4.0 | 37 | 1.4 | 1.0 | 49 | 0.2 | 53 | 1.06 | 267 |
| B16-11 | Mex. City | Green | PW | 114 | -- | 31 | 15 | 5 | 9 | 134 | 552 | 11 | 31 | 482 | 6.4 | 52 | 2.6 | 0.6 | 24 | 1.5 | 6 | 0.54 | 259 |
| B16-12 | Mex. City | Green | PW | 73 | 36 | 9 | 9 | 5 | 6 | 88 | 36 | 12 | 48 | 259 | 9.2 | 62 | 4.6 | 0.5 | 22 | 1.5 | 8 | 1.26 | 328 |
| B16-13 | Mex. City | Green | PW | 96 | 492 | 17 | 20 | 3 | 10 | 32 | 69 | 4 | 29 | 403 | 5.2 | 44 | 2.2 | 0.8 | 13 | 0.8 | 15 | 0.86 | 231 |
| B16-14 | Mex. City | Green | PW | 104 | 749 | 26 | 23 | 4 | 9 | 243 | 75 | 14 | 27 | 536 | 6.1 | 45 | 2.1 | 1.3 | 9 | 0.9 | 11 | 0.79 | 823 |
| B16-15 | Mex. City | Green | PW | 107 | 1 | 26 | 13 | 6 | 7 | 117 | 237 | 16 | 33 | 451 | 4.8 | 35 | 1.9 | 0.6 | 14 | 1.1 | 11 | 0.57 | 221 |
| B16-16 | Mex. City | Green | PW | 108 | -- | 27 | 16 | 6 | 9 | 333 | 289 | 13 | 32 | 472 | 5.1 | 42 | 2.3 | 0.8 | 64 | 1.7 | 11 | 0.55 | 233 |
| B16-17 | Mex. City | Green | PW | 126 | 26 | 12 | 11 | 2 | 5 | 39 | 46 | 9 | 47 | 301 | 2.6 | 26 | 0.9 | 0.1 | 61 | -- | 21 | 1.18 | 156 |
| B16-18 | Mex. City | Green | PW | 169 | -- | 23 | 16 | 5 | 9 | 21 | 69 | 14 | 23 | 621 | 5.0 | 39 | 2.0 | 0.3 | 54 | 0.6 | 53 | 1.93 | 239 |
| B16-19 | Mex. City | Aquamarine | PW | 109 | 294 | 16 | 15 | 3 | 8 | 21 | 50 | 4 | 45 | 362 | 3.3 | 29 | 1.4 | 0.4 | 9 | 0.5 | 17 | 1.16 | 160 |
| B16-2 | Mex. City | Aquamarine | PW | 125 | 160 | 10 | 9 | 2 | 7 | 46 | 81 | 7 | 18 | 263 | 3.5 | 25 | 1.3 | 1.0 | 24 | 7.2 | 45 | 1.06 | 147 |
| B16-20 | Mex. City | Green | PW | 115 | -- | 15 | 13 | 3 | 7 | 22 | 52 | 6 | 34 | 423 | 3.5 | 28 | 1.5 | 0.3 | 52 | 0.7 | 23 | 1.29 | 147 |
| B16-26 | Mex. City | Green | PW | 117 | 56 | 16 | 11 | 4 | 5 | 71 | 88 | 10 | 39 | 660 | 3.6 | 30 | 1.5 | 2.3 | 39 | 0.9 | 17 | 0.64 | 775 |
| B16-29 | Mex. City | Green | PW | 115 | 28 | 9 | 9 | 3 | 6 | 8833 | 53 | 26 | 30 | 427 | 2.9 | 24 | 1.3 | 0.7 | 77 | 15.4 | 41 | 0.96 | 184 |
| B16-3 | Mex. City | Green | PW | 118 | 343 | 15 | 21 | 3 | 10 | 19 | 62 | 8 | 28 | 534 | 4.3 | 37 | 1.6 | 0.3 | 8 | -- | 13 | 0.27 | 177 |
| B16-30 | Mex. City | Green | PW | 99 | 18 | 31 | 13 | 6 | 8 | 137 | 430 | 13 | 30 | 484 | 6.3 | 53 | 2.8 | 1.5 | 14 | 1.1 | 6 | 0.37 | 278 |
| B16-31 | Mex. City | Aquamarine | PW | 120 | 237 | 13 | 14 | 2 | 6 | 34 | 44 | 4 | 39 | 378 | 3.1 | 27 | 1.3 | 0.2 | 210 | 0.4 | 37 | 1.64 | 171 |
| B16-32 | Mex. City | Aquamarine | PW | 86 | 115 | 11 | 14 | 3 | 8 | 129 | 75 | 5 | 17 | 203 | 3.8 | 35 | 1.7 | 0.2 | 24 | 3.9 | 51 | 1.44 | 110 |
| B16-33 | Mex. City | Green | PW | 97 | 37 | 29 | 14 | 6 | 8 | 492 | 253 | 10 | 44 | 384 | 6.2 | 55 | 3.0 | 2.0 | 18 | 0.3 | 33 | 0.37 | 483 |
| B16-34 | Mex. City | Green | PW | 91 | 305 | 28 | 25 | 31 | 19 | 194 | 224 | 32 | 25 | 629 | 6.4 | 53 | 2.5 | 1.0 | 34 | -- | 5 | -- | 486 |
| B16-36G | Mex. City | Green | PW | 102 | 386 | 25 | 20 | 3 | 9 | 43 | 54 | 11 | 33 | 443 | 5.4 | 51 | 2.3 | 0.7 | 25 | 0.6 | 14 | 1.00 | 677 |
| B16-36P | Mex. City | Purple | PW | 104 | 338 | 25 | 21 | 4 | 8 | 36 | 61 | 15 | 31 | 438 | 5.2 | 49 | 2.0 | 0.6 | 29 | -- | 14 | 0.66 | 730 |
| B16-37 | Mex. City | Aquamarine | PW | 108 | 302 | 12 | 10 | 3 | 6 | 13 | 53 | 5 | 25 | 458 | 3.7 | 27 | 1.4 | 0.2 | 0 | 0.4 | 21 | 0.47 | 187 |
| B16-38 | Mex. City | Aquamarine | PW | 113 | 144 | 24 | 23 | 4 | 11 | 5950 | 93 | 8 | 39 | 420 | 6.0 | 56 | 2.4 | 0.2 | 10 | 2.9 | 13 | 0.73 | 324 |
| B16-4 | Mex. City | Aquamarine | PW | 128 | 90 | 7 | 9 | 2 | 5 | 22 | 40 | 5 | 20 | 258 | 2.5 | 19 | 1.0 | 0.3 | 41 | 0.4 | 57 | 1.64 | 107 |
| B16-49 | Mex. City | Aquamarine | PW | 131 | 57 | 15 | 13 | 2 | 6 | 53 | 42 | 6 | 48 | 469 | 3.9 | 32 | 1.6 | 0.7 | 30 | 0.7 | 18 | 1.56 | 199 |
| B16-5 | Mex. City | Aquamarine | PW | 119 | 174 | 13 | 9 | 2 | 6 | 72 | 84 | 3 | 55 | 276 | 2.8 | 25 | 1.2 | 0.4 | 15 | 1.1 | 20 | 1.30 | 168 |
| B16-6 | Mex. City | Aquamarine | PW | 90 | 55 | 13 | 11 | 2 | 6 | 56 | 61 | 3 | 33 | 139 | 6.9 | 65 | 3.7 | 0.2 | 47 | 17.1 | 31 | 1.81 | 104 |
| B16-8 | Mex. City | Green | PW | 112 | -- | 34 | 16 | 6 | 10 | 110 | 452 | 15 | 31 | 460 | 7.3 | 61 | 2.9 | 0.6 | 9 | 0.7 | 5 | 0.23 | 284 |
| B16-9 | Mex. City | Aquamarine | PW | 137 | 135 | 10 | 10 | 2 | 5 | 39 | 69 | 7 | 37 | 324 | 2.6 | 22 | 1.2 | 0.4 | 2 | 0.7 | 36 | 1.49 | 148 |
| J70-10 | Mex. City | Aquamarine | PW | 32 | 83 | 28 | 30 | 7 | 14 | 13 | 48 | 9 | 24 | 450 | 4.6 | 42 | 2.2 | 1.5 | 5 | 0.5 | 1 | 0.23 | 164 |
| J70-24 | Mex. City | Green | PW | 122 | 25 | 37 | 26 | 6 | 14 | 374 | 81 | 10 | 38 | 457 | 5.9 | 50 | 2.5 | 10.5 | 53 | 1.3 | 62 | 1.17 | 234 |
| TM-120 | Mex. City | Green | PW | 84 | 80 | 24 | 27 | 6 | 12 | 97 | 83 | 13 | 25 | 508 | 6.6 | 58 | 2.2 | 0.4 | 20 | 0.1 | 9 | 0.18 | 433 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TM-230 | Mex. City | Aquamarine | PW | 128 | 66 | 12 | 13 | 3 | 7 | 22 | 220 | 3 | 22 | 259 | 3.7 | 33 | 1.8 | 0.3 | 4 | 2.7 | 27 | 0.78 | 138 |
| TM-231 | Mex. City | Aquamarine | PW | 121 | 65 | 12 | 13 | 3 | 8 | 32 | 361 | 4 | 21 | 261 | 3.9 | 34 | 1.7 | 0.3 | 10 | 2.5 | 33 | 0.85 | 143 |
| TM-234 | Mex. City | Green | PW | 107 | 15 | 24 | 19 | 5 | 9 | 86 | 50 | 10 | 35 | 415 | 5.5 | 51 | 2.2 | 0.9 | 7 | 3.0 | 71 | 1.16 | 219 |
| TM-235 | Mex. City | Colorless | PW | 167 | 146 | 11 | 6 | 7 | 6 | 24 | 54 | 31 | 36 | 605 | 4.0 | 26 | 1.8 | 0.5 | 39 | 92.7 | 21 | 1.77 | 472 |
| TM-48 | Mex. City | Green | PW | 134 | 39 | 13 | 11 | 2 | 7 | 11 | 166 | 10 | 18 | 231 | 3.2 | 28 | 1.4 | 2.6 | 4 | -- | 49 | 0.44 | 136 |
| TM-49 | Mex. City | Green | PW | 127 | 59 | 9 | 10 | 2 | 5 | 20 | 55 | 10 | 25 | 266 | 2.8 | 25 | 0.9 | 0.4 | 39 | -- | 50 | 1.03 | 125 |
| TM-50 | Mex. City | Green | PW | 445 | 367 | 18 | 15 | 5 | 8 | 28 | 42 | 26 | 43 | 558 | 4.2 | 30 | 1.5 | 1.0 | 179 | 0.7 | 132 | 7.35 | 157 |
| TM-53 | Mex. City | Aquamarine | PW | 64 | 119 | 17 | 20 | 3 | 8 | 52 | 123 | 7 | 13 | 174 | 5.8 | 105 | 4.5 | 1.3 | 46 | 7.1 | 21 | 0.59 | 204 |
| B16-41 | Mex. City | Purple | Rod | 125 | 1346 | 32 | 16 | 7 | 8 | 4811 | 221 | 48 | 18 | 437 | 5.4 | 37 | 1.4 | 1.8 | 44 | 1.3 | 17 | 0.69 | 1670 |
| B16-50 | Mex. City | Green | Rod | 109 | 6 | 7 | 10 | 2 | 4 | 111 | 41 | 4 | 40 | 482 | 2.5 | 26 | 1.2 | 0.7 | 38 | 0.9 | 14 | 0.85 | 220 |
| B16-51 | Mex. City | Yellow | Rod | 121 | 45 | 12 | 11 | 4 | 6 | 121 | 73 | 11 | 30 | 479 | 3.1 | 27 | 1.5 | 2.2 | 52 | 3.8 | 38 | 1.14 | 678 |
| B16-52 | Mex. City | Green | Rod | 94 | 250 | 16 | 18 | 3 | 11 | 9662 | 74 | 17 | 29 | 406 | 4.9 | 43 | 2.0 | 0.5 | 15 | 7.1 | 17 | 0.73 | 180 |
| B16-53 | Mex. City | Blue | Rod | 117 | -- | 9 | 9 | 2 | 6 | 14067 | 60 | 13 | 52 | 404 | 2.6 | 23 | 1.0 | 0.4 | 56 | 2.6 | 33 | 1.35 | 163 |
| B16-54 | Mex. City | Amber | Rod | 109 | -- | 13 | 8 | 3 | 5 | 333 | 71 | 20 | 39 | 595 | 2.6 | 20 | 1.0 | 1.7 | 41 | 1.2 | 21 | 0.76 | 961 |
| B16-56 | Mex. City | Blue | Rod | 110 | 69 | 13 | 10 | 564 | 328 | 7233 | 91 | 537 | 49 | 500 | 4.0 | 37 | 1.7 | 6.7 | 40 | 4.4 | 22 | 1.04 | 191 |
| B16-58 | Mex. City | Purple | Rod | 121 | 33 | 13 | 11 | 3 | 6 | 60 | 61 | 14 | 33 | 475 | 3.1 | 28 | 1.4 | 1.5 | 152 | 1.0 | 45 | 1.09 | 850 |
| ApNi-10 | Mex. City | Colorless | Vessel | 50 | 48 | 13 | 12 | 25 | 13 | 13 | 45 | 63 | 18 | 445 | 3.3 | 23 | 1.1 | 1.9 | -- | 0.5 | 2 | 0.35 | 351 |
| ApNi-11 | Mex. City | Colorless | Vessel | 5 | -- | 3 | 2 | 3 | 8 | 12 | 4 | 783 | 99 | 25 | 0.7 | 2 | 0.1 | 0.9 | -- | 0.2 | 0 | 0.39 | 15 |
| ApNi-13 | Mex. City | Blue | Vessel | 97 | 142 | 13 | 15 | 3 | 11 | 13196 | 67 | 5 | 35 | 396 | 3.5 | 33 | 1.5 | 0.3 | 23 | 5.4 | 19 | 0.94 | 228 |
| ApNi-3 | Mex. City | Colorless | Vessel | 110 | 133 | 13 | 10 | 8 | 8 | 13 | 31 | 9 | 28 | 440 | 2.4 | 17 | 0.8 | 1.5 | 149 | 0.6 | 62 | 1.32 | 147 |
| ApNi-4 | Mex. City | Blue | Vessel | 28 | 871 | 29 | 17 | 2 | 5 | 7 | 17 | 8 | 15 | 492 | 5.2 | 64 | 4.4 | 1.0 | 31 | 1.9 | 1 | 0.68 | 528 |
| ApNi-9 | Mex. City | Colorless | Vessel | 139 | 12 | 23 | 14 | 6 | 7 | 19 | 68 | 15 | 36 | 458 | 4.4 | 32 | 1.5 | 0.4 | 28 | 1.0 | 21 | 1.18 | 295 |
| B16-25 | Mex. City | Colorless | Vessel | 5 | -- | 4 | 3 | 2 | 1 | 4 | 13 | 860 | 4 | 31 | 1.6 | 33 | 0.5 | 0.3 | 31 | 40.6 | 3308 | 0.06 | 73 |
| B16-27 | Mex. City | Aquamarine | Vessel | 118 | 504 | 17 | 15 | 3 | 9 | 136 | 43 | 5 | 54 | 280 | 4.3 | 39 | 2.1 | 0.5 | 50 | 1.2 | 16 | 1.45 | 187 |
| B16-44 | Mex. City | Colorless | Vessel | 173 | 105 | 11 | 9 | 3 | 5 | 18 | 39 | 9 | 31 | 405 | 3.5 | 27 | 1.3 | 0.4 | 14 | 0.4 | 24 | 1.33 | 142 |
| B16-46 | Mex. City | Colorless | Vessel | 130 | 49 | 19 | 16 | 4 | 7 | 34 | 62 | 13 | 30 | 601 | 3.6 | 32 | 1.4 | 0.6 | 58 | 0.5 | 63 | 1.49 | 238 |
| B16-48 | Mex. City | Aquamarine | Vessel | 9 | -- | 5 | 22 | 1 | 2 | 9 | 17 | 341 | 6 | 86 | 2.0 | 31 | 0.9 | 0.4 | 11 | 4.3 | 2470 | 0.27 | 378 |
| J70-11 | Mex. City | Aquamarine | Vessel | 105 | 1065 | 24 | 11 | 4 | 6 | 990 | 118 | 16 | 40 | 327 | 4.3 | 35 | 1.8 | 2.4 | 37 | 291.6 | 32 | 0.92 | 568 |
| J70-14 | Mex. City | Aquamarine | Vessel | 13 | 37 | 13 | 15 | 5 | 8 | 18 | 75 | 8 | 9 | 258 | 10.1 | 156 | 3.8 | 0.2 | 6 | 9.1 | 10 | 0.06 | 142 |
| J70-15 | Mex. City | Colorless | Vessel | 7 | -- | 6 | 3 | 2 | 11 | 20 | 8 | 2019 | 133 | 55 | 2.6 | 3 | 0.2 | 0.6 | -- | 0.8 | 1 | 0.67 | 25 |
| J70-18 | Mex. City | Colorless | Vessel | 335 | 171 | 11 | 7 | 6 | 6 | 21 | 45 | 25 | 29 | 791 | 3.5 | 29 | 1.2 | 0.3 | 60 | 11.3 | 22 | 1.93 | 458 |
| J70-19 | Mex. City | Blue | Vessel | 201 | 49 | 10 | 5 | 976 | 254 | 75 | 65 | 1978 | 32 | 500 | 3.3 | 20 | 1.3 | 61.9 | 22 | 4.8 | 19 | 2.63 | 138 |
| J70-20 | Mex. City | Blue | Vessel | 73 | 553 | 18 | 14 | 11 | 14 | 15626 | 65 | 102 | 17 | 544 | 4.7 | 32 | 1.5 | 0.8 | 48 | 257.3 | 52 | 0.71 | 192 |
| J70-21 | Mex. City | Aquamarine | Vessel | 124 | 997 | 26 | 22 | 3 | 9 | 383 | 35 | 6 | 43 | 407 | 6.0 | 33 | 1.4 | 0.7 | 37 | 1.4 | 19 | 1.11 | 274 |
| J70-23 | Mex. City | Colorless | Vessel | 589 | 144 | 11 | 6 | 3 | 5 | 24 | 59 | 12 | 32 | 810 | 3.7 | 25 | 0.9 | 0.3 | 28 | 3.6 | 35 | 2.21 | 227 |
| J70-26 | Mex. City | Blue | Vessel | 166 | 43 | 10 | 8 | 5 | 4 | 40 | 100 | 19 | 27 | 422 | 3.7 | 19 | 1.0 | 1.0 | 59 | 1.1 | 55 | 2.00 | 310 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Li35-8 | Mex. City | Blue | Vessel | 45 | 437 | 21 | 17 | 3 | 7 | 39 | 30 | 5 | 34 | 484 | 5.3 | 46 | 4.4 | 1.7 | 2 | 1.8 | 1 | 0.95 | 433 |
| Li35-9 | Mex. City | Blue | Vessel | 34 | 476 | 19 | 14 | 2 | 5 | 30 | 26 | 3 | 32 | 392 | 4.3 | 39 | 3.6 | 0.8 | 4 | 1.2 | 1 | 1.02 | 344 |
| TM-135 | Mex. City | Aquamarine | Vessel | 10 | 705 | 48 | 138 | 4 | 15 | 22 | 90 | 430 | 16 | 206 | 2.3 | 152 | 2.0 | 0.8 | 2 | 4.0 | 7 | 0.36 | 1323 |
| TM-142 | Mex. City | Aquamarine | Vessel | 37 | 838 | 23 | 10 | 2 | 5 | 3 | 19 | 4 | 17 | 378 | 5.3 | 33 | 2.7 | 0.5 | -- | 0.5 | 0 | 0.21 | 275 |
| TM-150 | Mex. City | Aquamarine | Vessel | 110 | 108 | 13 | 11 | 2 | 6 | 120 | 60 | 9 | 45 | 450 | 3.5 | 28 | 1.3 | 1.0 | 22 | 0.4 | 15 | 0.87 | 555 |
| TM-152 | Mex. City | Aquamarine | Vessel | 47 | 4 | 25 | 12 | 48 | 28 | 137 | 114 | 209 | 18 | 666 | 7.6 | 42 | 3.4 | 2.9 | 91 | 29.3 | 2 | 0.49 | 242 |
| TM-232 | Mex. City | Aquamarine | Vessel | 121 | 94 | 15 | 17 | 3 | 8 | 88 | 61 | 8 | 49 | 404 | 4.4 | 37 | 1.7 | 0.4 | 31 | 0.8 | 16 | 1.15 | 197 |
| TM-300 | Mex. City | Aquamarine | Vessel | 136 | 470 | 16 | 13 | 2 | 7 | 18 | 29 | 4 | 44 | 409 | 4.1 | 28 | 1.5 | 0.4 | 51 | 0.4 | 13 | 1.16 | 179 |
| TM-303 | Mex. City | Aquamarine | Vessel | 45 | 90 | 18 | 21 | 4 | 8 | 15 | 34 | 5 | 20 | 332 | 3.4 | 30 | 1.7 | 0.8 | 0 | 0.4 | 1 | 0.32 | 112 |
| TM-310 | Mex. City | Aquamarine | Vessel | 150 | 331 | 13 | 16 | 79 | 38 | 28 | 47 | 162 | 23 | 567 | 4.2 | 28 | 1.6 | 2.0 | 126 | 94.3 | 68 | 1.55 | 307 |
| TM-337 | Mex. City | Colorless | Vessel | 14 | -- | 6 | 8 | 21 | 10 | 50 | 36 | 19 | 17 | 746 | 2.1 | 14 | 0.9 | 1.2 | -- | 1973.3 | 4 | 0.24 | 267 |
| TM-360 | Mex. City | Aquamarine | Vessel | 121 | 43 | 13 | 11 | 2 | 7 | 21 | 154 | 5 | 18 | 225 | 3.3 | 29 | 1.4 | 2.3 | 12 | 0.8 | 43 | 0.84 | 128 |
| TM-38 | Mex. City | Blue | Vessel | 111 | 1050 | 21 | 18 | 3 | 9 | 21043 | 50 | 10 | 34 | 237 | 3.9 | 26 | 1.2 | 0.4 | 51 | 56.2 | 21 | 1.17 | 188 |
| HO-3 | Puebla | Aquamarine | Vessel | 13 | 22 | 21 | 26 | 18 | 12 | 139 | 209 | 254 | 18 | 213 | 6.7 | 93 | 4.3 | 0.8 | 21 | 27.0 | 94 | 0.78 | 1399 |
| LS-2 | Puebla | Aquamarine | Vessel | 10 | -- | 4 | 6 | 0 | 2 | 2 | 22 | 7 | 2 | 813 | 4.3 | 84 | 1.6 | -- | 2 | -- | -- | -- | 55 |
| MA-10 | Puebla | Colorless | Vessel | 11 | -- | 14 | 4 | 5 | 2 | -- | 5 | 30 | 4 | 59 | 1.6 | 31 | 1.1 | 1.4 | -- | 1.3 | 1 | 0.23 | 425 |
| MA-2 | Puebla | Aquamarine | Vessel | 28 | 506 | 23 | 14 | 3 | 5 | -- | 28 | 8 | 21 | 351 | 3.5 | 33 | 2.6 | 0.4 | 14 | 0.7 | -- | 0.35 | 346 |
| MA-4 | Puebla | Purple | Vessel | 17 | 526 | 22 | 12 | 28 | 24 | 709 | 774 | 86 | 10 | 265 | 10.1 | 25 | 1.7 | 1.0 | 1 | 158.3 | 22 | 0.15 | 6557 |
| MA-6 | Puebla | Aquamarine | Vessel | 44 | 604 | 19 | 11 | 9 | 8 | 23 | 145 | 75 | 18 | 294 | 4.6 | 54 | 7.7 | 1.4 | 22 | 31.1 | 3 | 0.33 | 891 |
| MA-7 | Puebla | Aquamarine | Vessel | 33 | 870 | 28 | 19 | 5 | 8 | 2 | 44 | 10 | 4 | 285 | 5.9 | 36 | 1.6 | 0.2 | 13 | 2.2 | -- | -- | 431 |
| MA-9 | Puebla | Colorless | Vessel | 5 | -- | 5 | 3 | 1 | 5 | 9 | 4 | 1388 | 78 | 51 | 2.3 | 2 | 0.1 | 1.5 | -- | 0.2 | 1 | 0.27 | 10 |
| SJD-10 | Puebla | Blue | Vessel | 26 | 361 | 22 | 15 | 162 | 71 | 39 | 27 | 313 | 30 | 356 | 5.2 | 46 | 3.6 | 2.8 | 3 | 1.0 | 1 | 0.80 | 1004 |
| SJD-11 | Puebla | Colorless | Vessel | 39 | 545 | 21 | 14 | 3 | 5 | 28 | 26 | 8 | 31 | 408 | 4.6 | 39 | 3.7 | 1.2 | -- | 4.3 | 1 | 0.86 | 395 |
| SJD-12 | Puebla | Blue | Vessel | 25 | 330 | 21 | 14 | 211 | 92 | 41 | 28 | 409 | 29 | 352 | 5.1 | 49 | 3.8 | 3.3 | 2 | 1.0 | 1 | 0.74 | 1166 |
| SJD-13 | Puebla | Aquamarine | Vessel | 33 | 558 | 21 | 13 | 3 | 6 | -- | 29 | 19 | 18 | 336 | 4.1 | 33 | 2.4 | 0.6 | 21 | 5.2 | 0 | 0.31 | 466 |
| SJD-14 | Puebla | Colorless | Vessel | 39 | 530 | 21 | 13 | 2 | 6 | 29 | 25 | 8 | 31 | 394 | 4.4 | 39 | 3.5 | 1.0 | -- | 4.7 | 1 | 0.85 | 395 |
| SJD-15 | Puebla | Colorless | Vessel | 16 | 81 | 21 | 24 | 4 | 20 | 8 | 61 | 5 | 12 | 939 | 4.5 | 32 | 2.3 | 2.4 | 6 | 3.5 | 2 | 0.24 | 241 |
| SJD-19 | Puebla | Blue | Vessel | 17 | 306 | 19 | 13 | 3 | 5 | 9 | 24 | 3 | 16 | 236 | 4.0 | 28 | 3.1 | 0.3 | 2 | 2.0 | 0 | 0.42 | 385 |
| SJD-2 | Puebla | Aquamarine | Vessel | 14 | 325 | 17 | 9 | 3 | 3 | 48 | 29 | 9 | 13 | 231 | 3.1 | 21 | 1.6 | 0.7 | 31 | 2.2 | -- | 0.17 | 329 |
| SJD-20 | Puebla | Colorless | Vessel | 17 | -- | 6 | 3 | 2 | 11 | 23 | 7 | 1740 | 130 | 40 | 1.1 | 2 | 0.2 | 1.7 | 45 | 0.6 | 1 | 0.54 | 27 |
| SJD-21 | Puebla | Colorless | Vessel | 16 | 87 | 19 | 25 | 4 | 19 | 10 | 66 | 7 | 14 | 989 | 4.5 | 33 | 2.6 | 3.1 | -- | 2.0 | 2 | 0.30 | 265 |
| SJD-25 | Puebla | Aquamarine | Vessel | 18 | 378 | 18 | 12 | 2 | 4 | 18 | 28 | 8 | 18 | 285 | 3.7 | 30 | 2.8 | 0.1 | 0 | 0.1 | -- | 0.33 | 388 |
| SJD-5 | Puebla | Green | Vessel | 23 | 28 | 40 | 43 | 9 | 32 | 63 | 210 | 46 | 55 | 562 | 14.0 | 196 | 7.0 | 1.0 | 3 | 22.3 | 1 | 1.25 | 2256 |
| SJD-7 | Puebla | Aquamarine | Vessel | 41 | 547 | 21 | 13 | 3 | 5 | 28 | 31 | 12 | 30 | 398 | 4.4 | 39 | 3.2 | 1.0 | 32 | 4.0 | 0 | 0.66 | 377 |
| SJD-9 | Puebla | Aquamarine | Vessel | 19 | 279 | 19 | 10 | 3 | 4 | 19 | 41 | 10 | 22 | 308 | 3.6 | 25 | 2.4 | 1.8 | 11 | 0.2 | -- | 0.45 | 375 |
| SR-3 | Puebla | Amber | Vessel | 15 | 1671 | 44 | 18 | 4 | 13 | 57 | 109 | 374 | 12 | 193 | 3.2 | 69 | 1.6 | 0.7 | 3 | 4.8 | 14 | 0.31 | 1298 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BCN-08 | Barcelona | Colorless | Vessel | 20 | -- | 10 | 8 | 3 | 7 | 35 | 204 | 9 | 28 | 472 | 4.7 | 47 | 2.0 | 0.4 | -- | 87.2 | 1 | 0.59 | 210 |
| BCN-10 | Barcelona | Colorless | Vessel | 227 | 22 | 7 | 4 | 4 | 6 | 59 | 38 | 8 | 40 | 1173 | 3.4 | 32 | 1.3 | 0.3 | -- | 115.9 | 2 | 0.30 | 109 |
| BCN-11 | Barcelona | Aquamarine | Vessel | 76 | 48 | 18 | 12 | 4 | 13 | 86 | 70 | 6 | 17 | 598 | 7.8 | 58 | 3.0 | 0.3 | -- | 57.1 | 30 | 0.33 | 177 |
| BCN-12 | Barcelona | Colorless | Vessel | 28 | -- | 11 | 6 | 18 | 16 | 106 | 63 | 35 | 23 | 500 | 5.0 | 39 | 1.7 | 1.1 | -- | 671.8 | 2 | 0.52 | 203 |
| BCN-13 | Barcelona | Aquamarine | Vessel | 61 | 117 | 19 | 14 | 5 | 15 | 69 | 89 | 13 | 15 | 581 | 8.8 | 76 | 3.7 | 0.2 | 11 | 44.5 | 13 | 0.33 | 180 |
| BCN-14 | Barcelona | Aquamarine | Vessel | 31 | 112 | 19 | 15 | 5 | 15 | 78 | 82 | 7 | 12 | 527 | 10.5 | 135 | 4.7 | 0.5 | 23 | 71.3 | 3 | 0.32 | 224 |
| BCN-15 | Barcelona | Green | Vessel | 31 | 101 | 19 | 13 | 5 | 14 | 77 | 90 | 6 | 13 | 501 | 9.7 | 126 | 4.4 | 0.5 | 35 | 69.3 | 3 | 0.38 | 220 |
| BCN-17 | Barcelona | Colorless | Vessel | 15 | 32 | 9 | 6 | 6 | 7 | 40 | 45 | 20 | 16 | 595 | 4.0 | 29 | 1.6 | 0.7 | 12 | 73.1 | 1 | 0.13 | 119 |
| BCN-18 | Barcelona | Colorless | Vessel | 69 | 80 | 12 | 8 | 6 | 9 | 233 | 45 | 8 | 12 | 266 | 5.2 | 45 | 2.7 | 0.4 | 350 | 1061.0 | 4 | 0.18 | 142 |
| BCN-2 | Barcelona | Aquamarine | Vessel | 44 | 88 | 17 | 11 | 8 | 15 | 196 | 88 | 16 | 16 | 566 | 7.3 | 63 | 3.0 | 0.7 | 1 | 256.3 | 3 | 0.38 | 242 |
| BCN-20 | Barcelona | Aquamarine | Vessel | 68 | 120 | 18 | 12 | 6 | 13 | 85 | 131 | 8 | 14 | 552 | 7.8 | 67 | 3.5 | 0.7 | 58 | 49.5 | 36 | 0.27 | 307 |
| BCN-22 | Barcelona | Green | Vessel | 50 | -- | 16 | 9 | 16 | 16 | 371 | 99 | 43 | 29 | 522 | 7.9 | 68 | 2.8 | 1.0 | -- | 545.2 | 4 | 0.64 | 314 |
| BCN-23 | Barcelona | Green | Vessel | 37 | 73 | 19 | 14 | 5 | 16 | 83 | 83 | 8 | 14 | 563 | 10.6 | 132 | 4.5 | 0.5 | -- | 89.3 | 4 | 0.40 | 245 |
| BCN-24 | Barcelona | Colorless | Vessel | 233 | 44 | 6 | 4 | 3 | 5 | 30 | 39 | 5 | 20 | 1322 | 3.0 | 30 | 1.3 | 0.8 | 43 | 130.2 | 1 | 0.28 | 66 |
| BCN-25 | Barcelona | Colorless | Vessel | 175 | 4 | 7 | 5 | 2 | 4 | 21 | 30 | 4 | 21 | 1060 | 2.9 | 25 | 1.2 | 0.3 | -- | 9.3 | 95 | 0.29 | 57 |
| BCN-3 | Barcelona | Colorless | Vessel | 31 | 101 | 27 | 16 | 6 | 15 | 51 | 97 | 11 | 12 | 358 | 10.1 | 71 | 4.6 | 0.6 | 46 | 4.9 | 24 | 0.38 | 283 |
| BCN-4 | Barcelona | Aquamarine | Vessel | 29 | 32 | 15 | 12 | 33 | 20 | 32 | 72 | 42 | 22 | 608 | 4.8 | 39 | 2.2 | 0.9 | 31 | 10.7 | 72 | 0.79 | 170 |
| BCN-5 | Barcelona | Colorless | Vessel | 49 | 83 | 14 | 7 | 4 | 11 | 42 | 134 | 25 | 8 | 381 | 7.2 | 36 | 2.4 | 0.1 | 8 | 4.9 | 30 | 0.19 | 101 |
| BCN-6 | Barcelona | Aquamarine | Vessel | 43 | 121 | 24 | 17 | 7 | 15 | 67 | 107 | 18 | 17 | 499 | 10.3 | 99 | 4.7 | 0.7 | 37 | 42.9 | 33 | 0.65 | 316 |
| BCN-7 | Barcelona | Colorless | Vessel | 29 | 25 | 9 | 4 | 7 | 7 | 56 | 61 | 14 | 13 | 354 | 3.4 | 25 | 1.4 | 0.2 | 31 | 1150.3 | 2 | 0.14 | 125 |
| SBG-1 | Vic | Green | Vessel | 35 | 75 | 24 | 17 | 5 | 13 | 30 | 96 | 37 | 20 | 424 | 11.5 | 96 | 4.8 | 1.2 | 18 | 17.1 | 45 | 0.06 | 446 |
| SBG-10d | Vic | Aquamarine | Vessel | 27 | -- | 19 | 12 | 7 | 10 | 61 | 83 | 49 | 25 | 404 | 9.6 | 129 | 4.5 | 1.2 | 14 | 53.2 | 314 | 0.35 | 509 |
| SBG-10e | Vic | Colorless | Vessel | 48 | 76 | 15 | 9 | 8 | 11 | 40 | 87 | 27 | 13 | 511 | 6.6 | 55 | 2.6 | 0.9 | 0 | 3.1 | 59 | -- | 270 |
| SBG-10f | Vic | Aquamarine | Vessel | 40 | 71 | 25 | 19 | 5 | 14 | 28 | 96 | 39 | 25 | 424 | 12.0 | 95 | 4.8 | 0.8 | 46 | 35.0 | 79 | 0.31 | 504 |
| SBG-2 | Vic | Blue | Vessel | 31 | 2 | 13 | 7 | 76 | 33 | 244 | 112 | 68 | 20 | 397 | 5.8 | 50 | 2.3 | 4.1 | 29 | 1041.5 | 1 | 0.11 | 361 |
| SBG-20a | Vic | Blue | Vessel | 30 | 9 | 7 | 4 | 354 | 177 | 44 | 88 | 731 | 15 | 302 | 3.6 | 24 | 1.1 | 1.7 | 13 | 257.7 | -- | 0.02 | 145 |
| SBG-20b | Vic | Colorless | Vessel | 42 | 19 | 12 | 8 | 17 | 17 | 23 | 76 | 138 | 22 | 442 | 4.6 | 38 | 1.8 | 0.9 | 33 | 12.8 | 1860 | 0.03 | 253 |
| SBG-20f | Vic | Aquamarine | Vessel | 36 | 71 | 21 | 16 | 5 | 13 | 38 | 104 | 16 | 12 | 428 | 10.2 | 79 | 4.3 | 0.8 | 43 | 10.1 | 27 | 0.31 | 403 |
| ApNi-8 | Imported | Red | Vessel | 102 | 1066 | 25 | 20 | 3 | 9 | 7256 | 48 | 7 | 22 | 290 | 4.7 | 30 | 1.2 | 0.4 | 39 | 2.8 | 19 | 0.57 | 202 |
| J70-13 | Imported | Colorless | Vessel | 14 | 8 | 7 | 10 | 14 | 13 | 23 | 30 | 17 | 13 | 776 | 2.7 | 14 | 1.1 | 1.1 | 5 | 276.7 | 2 | 0.24 | 170 |
| Li35-7 | Imported | Aquamarine | Vessel | 7 | -- | 13 | 5 | 1 | 2 | 3 | 7 | 8 | 2 | 21 | 2.0 | 173 | 2.1 | 0.7 | 7 | 1.0 | 2 | 0.04 | 27 |
| Li35-3 | Imported | Green | Vessel | 23 | -- | 40 | 28 | 4 | 11 | 6 | 33 | 9 | 32 | 285 | 9.1 | 58 | 5.2 | 0.8 | 42 | 3.5 | 2 | 0.88 | 280 |
| J70-2 | Imported | Green | Vessel | 9 | 13 | 20 | 19 | 5 | 15 | 87 | 223 | 9 | 31 | 617 | 7.5 | 154 | 5.2 | 3.1 | 22 | 34.9 | 2 | 0.42 | 1251 |
| J70-32 | Imported | Green | Vessel | 22 | 23 | 24 | 24 | 5 | 13 | 11 | 158 | 19 | 16 | 952 | 6.1 | 70 | 3.9 | 0.8 | 20 | 3.5 | 1 | 0.34 | 341 |
| J70-35 | Imported | Green | Vessel | 18 | 102 | 31 | 38 | 7 | 21 | 61 | 57 | 13 | 28 | 582 | 11.2 | 191 | 5.3 | 1.4 | 65 | 11.4 | 2 | 0.69 | 411 |
| J70-44 | Imported | Green | Vessel | 20 | 141 | 27 | 25 | 6 | 19 | 92 | 226 | 20 | 36 | 999 | 10.9 | 112 | 5.2 | 1.3 | 8 | 75.1 | 3 | 0.73 | 816 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J70-46 | Imported | Green | Vessel | 19 | 115 | 23 | 22 | 6 | 17 | 101 | 215 | 16 | 39 | 971 | 8.9 | 96 | 4.2 | 0.9 | 25 | 72.5 | 3 | 0.83 | 868 |
| J70-40 | Imported | Green | Vessel | 25 | 39 | 33 | 30 | 5 | 17 | 28 | 206 | 15 | 23 | 1391 | 15.6 | 129 | 4.0 | 1.6 | 45 | 13.1 | 2 | 0.59 | 2556 |
| Li35-5 | Imported | Green | Vessel | 20 | 100 | 25 | 23 | 6 | 17 | 94 | 244 | 16 | 39 | 932 | 9.4 | 104 | 4.6 | 2.5 | 22 | 71.0 | 3 | 0.72 | 737 |
| Li35-4 | Imported | Green | Vessel | 27 | -- | 42 | 29 | 4 | 11 | 7 | 35 | 10 | 52 | 234 | 8.5 | 56 | 5.1 | 1.3 | 46 | 2.7 | 1 | 1.47 | 348 |
| MA-8 | Imported | Aquamarine | Vessel | 126 | -- | 5 | 4 | 0 | 3 | 3 | 13 | 47 | 66 | 59 | 1.6 | 28 | 1.5 | 0.1 | 0 | 1.5 | 3 | 9.60 | 10 |

Table III. (*continued…*)

| **Sample** | **La** | **Ce** | **Pr** | **Nd** | **Sm** | **Eu** | **Gd** | **Tb** | **Dy** | **Ho** | **Er** | **Tm** | **Yb** | **Lu** | **Hf** | **Ta** | **Au** | **Tl** | **Pb** | **Bi** | **Th** | **U** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ApNi-2 | 5.58 | 10.99 | 1.24 | 4.91 | 0.89 | 0.11 | 0.81 | 0.03 | 0.73 | 0.01 | 0.34 | -- | 0.37 | -- | 0.9 | -- | 0.4 | 0.05 | 22 | -- | 1.0 | 0.64 |
| ApNi-7 | 4.97 | 9.83 | 1.14 | 4.59 | 0.79 | 0.03 | 0.75 | 0.03 | 0.67 | -- | 0.27 | -- | 0.29 | -- | 0.7 | 3.8 | 3.9 | 0.02 | 157 | -- | 0.9 | 0.67 |
| B16-11 | 6.81 | 13.29 | 1.73 | 6.62 | 1.55 | 0.57 | 1.43 | 0.29 | 1.29 | 0.33 | 0.68 | 0.22 | 0.83 | 0.24 | 1.6 | 1.9 | 41.3 | 0.09 | 428 | -- | 1.8 | 0.71 |
| B16-12 | 13.00 | 22.77 | 3.18 | 11.57 | 2.26 | 0.56 | 1.84 | 0.36 | 1.58 | 0.40 | 1.01 | 0.26 | 1.09 | 0.30 | 2.2 | 3.6 | 11.7 | 0.10 | 9 | 1 | 5.8 | 1.22 |
| B16-13 | 5.29 | 9.50 | 1.43 | 5.32 | 1.44 | 0.55 | 1.36 | 0.38 | 1.05 | 0.39 | 0.69 | 0.27 | 0.75 | 0.27 | 1.3 | 1.7 | 2.4 | 0.15 | 12 | -- | 1.6 | 0.84 |
| B16-14 | 5.82 | 11.29 | 1.54 | 5.96 | 1.52 | 0.56 | 1.39 | 0.35 | 1.18 | 0.39 | 0.72 | 0.25 | 0.84 | 0.30 | 1.3 | 0.9 | 2.1 | 0.19 | 15 | -- | 1.6 | 1.12 |
| B16-15 | 5.31 | 9.57 | 1.23 | 4.96 | 1.16 | 0.43 | 1.03 | 0.24 | 1.00 | 0.26 | 0.59 | 0.17 | 0.60 | 0.21 | 1.0 | 1.4 | 1.7 | 0.13 | 441 | -- | 1.3 | 0.76 |
| B16-16 | 5.95 | 10.90 | 1.50 | 5.20 | 1.36 | 0.47 | 1.19 | 0.26 | 1.04 | 0.27 | 0.60 | 0.19 | 0.63 | 0.23 | 1.3 | 3.7 | 14.3 | 0.15 | 427 | -- | 1.5 | 0.80 |
| B16-17 | 2.79 | 5.78 | 0.64 | 2.70 | 0.67 | -- | 0.34 | -- | 0.42 | -- | 0.17 | -- | 0.16 | -- | 0.6 | 1.1 | 5.3 | 0.14 | 17 | -- | 0.7 | 0.17 |
| B16-18 | 5.46 | 9.92 | 1.24 | 5.17 | 1.05 | 0.44 | 1.07 | 0.27 | 0.96 | 0.28 | 0.64 | 0.18 | 0.67 | 0.21 | 1.1 | 0.2 | 1.6 | 0.14 | 29 | -- | 1.1 | 0.65 |
| B16-19 | 3.62 | 7.49 | 0.94 | 3.66 | 0.99 | 0.28 | 0.83 | 0.20 | 0.73 | 0.24 | 0.44 | 0.17 | 0.47 | 0.17 | 0.9 | 2.6 | 0.3 | 0.07 | 16 | -- | 1.2 | 0.39 |
| B16-2 | 3.93 | 7.86 | 1.03 | 4.04 | 1.03 | 0.29 | 0.90 | 0.23 | 0.78 | 0.25 | 0.47 | 0.18 | 0.49 | 0.17 | 0.8 | 3.7 | 0.5 | 0.01 | 26 | -- | 1.2 | 0.33 |
| B16-20 | 3.91 | 6.94 | 1.01 | 3.46 | 0.88 | 0.37 | 0.79 | 0.23 | 0.86 | 0.22 | 0.53 | 0.16 | 0.51 | 0.21 | 0.9 | 0.2 | 1.9 | 0.16 | 25 | -- | 1.0 | 0.43 |
| B16-26 | 4.59 | 7.89 | 1.03 | 3.71 | 0.83 | 0.33 | 0.78 | 0.22 | 0.76 | 0.22 | 0.52 | 0.16 | 0.57 | 0.19 | 0.9 | 1.5 | 5.1 | 0.12 | 14 | -- | 1.2 | 1.06 |
| B16-29 | 3.10 | 5.68 | 0.77 | 2.83 | 0.69 | 0.30 | 0.68 | 0.19 | 0.56 | 0.19 | 0.40 | 0.16 | 0.40 | 0.20 | 0.8 | 2.3 | 5.7 | 0.12 | 185 | -- | 0.9 | 0.36 |
| B16-3 | 4.71 | 9.68 | 1.23 | 4.88 | 1.15 | 0.03 | 0.76 | 0.04 | 0.74 | 0.00 | 0.32 | -- | 0.34 | -- | 0.9 | -- | -- | 0.07 | 7 | -- | 1.1 | 0.41 |
| B16-30 | 7.14 | 13.82 | 1.75 | 6.66 | 1.57 | 0.54 | 1.33 | 0.29 | 1.18 | 0.30 | 0.71 | 0.20 | 0.79 | 0.24 | 1.5 | 0.7 | 3.7 | 0.08 | 181 | -- | 1.8 | 0.89 |
| B16-31 | 3.29 | 6.63 | 0.87 | 3.58 | 0.84 | 0.26 | 0.79 | 0.21 | 0.72 | 0.23 | 0.48 | 0.16 | 0.43 | 0.17 | 0.9 | 4.7 | -- | 0.09 | 19 | -- | 1.0 | 0.50 |
| B16-32 | 3.83 | 7.79 | 0.99 | 3.84 | 1.02 | 0.29 | 0.90 | 0.21 | 0.79 | 0.25 | 0.49 | 0.17 | 0.49 | 0.17 | 1.1 | 1.3 | -- | 0.07 | 56 | -- | 1.3 | 0.32 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B16-33 | 8.29 | 18.01 | 1.86 | 7.50 | 1.44 | 0.13 | 1.04 | 0.09 | 1.08 | 0.06 | 0.52 | -- | 0.54 | -- | 1.5 | 1.4 | 1.1 | 0.01 | 14 | -- | 2.3 | 0.68 |
| B16-34 | 7.01 | 14.32 | 1.74 | 6.87 | 1.60 | 0.19 | 1.21 | 0.11 | 1.15 | 0.08 | 0.46 | -- | 0.42 | -- | 1.2 | 1.8 | -- | 0.03 | 285 | 5 | 1.6 | 1.43 |
| B16-36G | 5.60 | 10.90 | 1.39 | 5.90 | 1.52 | 0.45 | 1.29 | 0.27 | 1.15 | 0.32 | 0.68 | 0.20 | 0.66 | 0.20 | 1.4 | 0.7 | -- | 0.15 | 11 | -- | 1.6 | 1.19 |
| B16-36P | 5.46 | 10.83 | 1.29 | 5.69 | 1.09 | 0.07 | 0.98 | 0.08 | 0.90 | 0.04 | 0.40 | -- | 0.41 | -- | 1.1 | -- | -- | 0.16 | 12 | -- | 1.4 | 1.06 |
| B16-37 | 3.39 | 7.18 | 0.95 | 3.92 | 1.07 | 0.28 | 0.94 | 0.23 | 0.89 | 0.26 | 0.47 | 0.17 | 0.50 | 0.18 | 0.8 | 0.5 | -- | 0.07 | 8 | -- | 1.2 | 0.45 |
| B16-38 | 5.88 | 11.91 | 1.56 | 6.20 | 1.69 | 0.43 | 1.36 | 0.28 | 1.20 | 0.31 | 0.64 | 0.21 | 0.65 | 0.21 | 1.6 | 0.6 | -- | 0.02 | 43 | -- | 1.6 | 0.62 |
| B16-4 | 2.53 | 4.84 | 0.63 | 2.60 | 0.71 | 0.20 | 0.62 | 0.17 | 0.59 | 0.20 | 0.33 | 0.14 | 0.32 | 0.15 | 0.6 | 0.4 | -- | 0.04 | 19 | -- | 0.8 | 0.17 |
| B16-49 | 4.21 | 8.16 | 1.03 | 4.28 | 1.07 | 0.29 | 0.92 | 0.21 | 0.77 | 0.25 | 0.49 | 0.16 | 0.51 | 0.18 | 1.0 | 0.3 | -- | 0.12 | 16 | -- | 1.3 | 0.37 |
| B16-5 | 3.31 | 6.55 | 0.83 | 3.07 | 0.82 | 0.24 | 0.76 | 0.18 | 0.68 | 0.22 | 0.38 | 0.15 | 0.43 | 0.17 | 0.8 | 0.9 | 0.1 | 0.09 | 22 | -- | 1.0 | 0.42 |
| B16-6 | 8.17 | 16.36 | 1.96 | 7.61 | 1.82 | 0.38 | 1.45 | 0.29 | 1.25 | 0.36 | 0.78 | 0.23 | 0.92 | 0.25 | 2.1 | 8.1 | 0.1 | 0.05 | 20 | -- | 4.4 | 0.86 |
| B16-8 | 8.95 | 17.31 | 2.11 | 8.25 | 1.64 | 0.24 | 1.38 | 0.12 | 1.35 | 0.11 | 0.57 | -- | 0.56 | -- | 1.4 | -- | -- | 0.01 | 292 | -- | 2.0 | 0.68 |
| B16-9 | 2.88 | 5.74 | 0.75 | 2.99 | 0.75 | 0.22 | 0.66 | 0.18 | 0.66 | 0.22 | 0.37 | 0.15 | 0.36 | 0.16 | 0.7 | 0.8 | -- | 0.02 | 23 | -- | 0.9 | 0.25 |
| J70-10 | 4.95 | 10.15 | 1.28 | 5.36 | 1.24 | 0.39 | 1.05 | 0.26 | 0.98 | 0.29 | 0.58 | 0.19 | 0.55 | 0.19 | 1.1 | 2.4 | -- | -- | 4 | -- | 1.1 | 0.48 |
| J70-24 | 6.14 | 13.28 | 1.66 | 6.86 | 1.39 | 0.17 | 1.25 | 0.11 | 1.03 | 0.06 | 0.44 | -- | 0.43 | 0.00 | 1.1 | -- | 6.4 | 0.05 | 5 | -- | 1.2 | 1.16 |
| TM-120 | 6.76 | 13.52 | 1.73 | 6.92 | 1.34 | 0.22 | 1.30 | 0.09 | 1.21 | 0.08 | 0.54 | -- | 0.53 | 0.03 | 1.5 | 5.2 | 4.4 | 0.02 | 11 | -- | 1.6 | 0.59 |
| TM-230 | 4.07 | 8.09 | 1.08 | 4.55 | 1.10 | 0.29 | 0.83 | 0.20 | 0.78 | 0.25 | 0.48 | 0.17 | 0.43 | 0.19 | 1.1 | 2.3 | -- | -- | 86 | -- | 1.3 | 0.93 |
| TM-231 | 4.33 | 8.53 | 1.13 | 4.39 | 1.16 | 0.33 | 0.94 | 0.22 | 0.87 | 0.23 | 0.49 | 0.17 | 0.51 | 0.18 | 1.0 | 13.1 | -- | 0.02 | 84 | -- | 1.3 | 0.29 |
| TM-234 | 5.68 | 11.64 | 1.49 | 6.00 | 1.17 | 0.09 | 0.99 | 0.07 | 0.95 | 0.03 | 0.46 | -- | 0.42 | -- | 1.3 | -- | -- | 0.01 | 15 | -- | 1.4 | 0.53 |
| TM-235 | 5.40 | 9.76 | 1.31 | 4.44 | 0.96 | 0.36 | 0.89 | 0.23 | 0.77 | 0.23 | 0.50 | 0.17 | 0.59 | 0.21 | 0.8 | 3.4 | 20.4 | 0.14 | 234 | 1 | 1.2 | 0.53 |
| TM-48 | 3.74 | 7.49 | 0.93 | 3.74 | 0.74 | 0.05 | 0.61 | 0.04 | 0.70 | 0.07 | 0.37 | -- | 0.33 | 0.04 | 0.8 | 2.0 | 0.5 | 0.02 | 25 | -- | 1.1 | 0.27 |
| TM-49 | 2.90 | 5.78 | 0.71 | 3.03 | 0.53 | -- | 0.49 | -- | 0.48 | -- | 0.11 | -- | 0.20 | -- | 0.6 | 3.4 | 10.3 | 0.01 | 21 | -- | 0.8 | 0.13 |
| TM-50 | 3.84 | 8.52 | 1.10 | 4.47 | 0.97 | 0.02 | 0.71 | 0.03 | 0.72 | -- | 0.31 | -- | 0.27 | -- | 0.8 | -- | 0.4 | 0.08 | 16 | -- | 0.9 | 0.24 |
| TM-53 | 5.00 | 9.76 | 1.30 | 5.23 | 1.23 | 0.33 | 1.11 | 0.27 | 1.06 | 0.33 | 0.67 | 0.22 | 0.78 | 0.23 | 2.9 | 2.6 | 1.9 | 0.03 | 194 | 1 | 2.1 | 0.74 |
| B16-41 | 6.61 | 10.54 | 1.32 | 5.25 | 1.25 | 0.51 | 1.21 | 0.27 | 1.03 | 0.32 | 0.63 | 0.20 | 0.68 | 0.23 | 0.8 | 0.2 | 2.0 | 0.55 | 81 | 126 | 1.2 | 3.06 |
| B16-50 | 2.92 | 5.69 | 0.83 | 2.83 | 0.80 | 0.32 | 0.63 | 0.20 | 0.64 | 0.20 | 0.37 | 0.16 | 0.41 | 0.20 | 0.8 | 3.3 | 8.5 | 0.13 | 21 | -- | 0.9 | 0.35 |
| B16-51 | 4.01 | 6.98 | 0.91 | 3.25 | 0.90 | 0.35 | 0.70 | 0.19 | 0.62 | 0.21 | 0.43 | 0.16 | 0.49 | 0.19 | 0.8 | 0.2 | 3.5 | 0.12 | 9 | -- | 1.0 | 1.48 |
| B16-52 | 4.97 | 8.92 | 1.19 | 5.14 | 1.07 | 0.43 | 1.22 | 0.25 | 0.92 | 0.26 | 0.60 | 0.18 | 0.65 | 0.22 | 1.2 | 0.2 | 7.7 | 0.14 | 27 | -- | 1.4 | 0.66 |
| B16-53 | 2.77 | 4.82 | 0.67 | 2.67 | 0.60 | 0.27 | 0.70 | 0.19 | 0.58 | 0.19 | 0.36 | 0.16 | 0.43 | 0.18 | 0.7 | 0.5 | 4.8 | 0.18 | 26 | -- | 0.9 | 0.23 |
| B16-54 | 2.94 | 5.06 | 0.69 | 2.58 | 0.75 | 0.32 | 0.77 | 0.20 | 0.55 | 0.18 | 0.38 | 0.15 | 0.46 | 0.18 | 0.6 | 2.4 | 2.2 | 0.38 | 12 | -- | 0.8 | 0.82 |
| B16-56 | 3.90 | 7.40 | 0.98 | 3.64 | 0.90 | 0.36 | 0.88 | 0.22 | 0.75 | 0.23 | 0.49 | 0.17 | 0.55 | 0.20 | 1.1 | 0.7 | 24.1 | 0.19 | 67 | 274 | 1.2 | 5.44 |
| B16-58 | 3.42 | 5.96 | 0.77 | 2.98 | 0.83 | 0.34 | 0.76 | 0.23 | 0.64 | 0.22 | 0.42 | 0.17 | 0.45 | 0.20 | 0.9 | 5.1 | 67.2 | 0.16 | 10 | -- | 0.9 | 0.81 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ApNi-10 | 3.02 | 5.94 | 0.71 | 3.23 | 0.74 | 0.19 | 0.81 | 0.09 | 0.62 | 0.11 | 0.26 | 0.01 | 0.29 | 0.08 | 0.6 | 3.4 | 11.7 | 0.08 | 5 | 4 | 0.7 | 0.84 |
| ApNi-11 | 0.49 | 0.78 | 0.07 | 0.40 | 0.11 | -- | 0.21 | 0.01 | 0.05 | -- | -- | -- | 0.11 | 0.04 | -- | 5.0 | -- | 0.02 | 1 | -- | 0.1 | 0.36 |
| ApNi-13 | 3.62 | 7.17 | 0.95 | 3.78 | 0.98 | 0.34 | 0.87 | 0.21 | 0.71 | 0.23 | 0.50 | 0.17 | 0.54 | 0.20 | 1.0 | 0.2 | 2.9 | 0.16 | 48 | -- | 1.2 | 0.35 |
| ApNi-3 | 2.28 | 4.31 | 0.53 | 2.35 | 0.63 | 0.10 | 0.59 | 0.05 | 0.37 | 0.06 | 0.16 | -- | 0.30 | 0.06 | 0.4 | 1.0 | -- | 0.06 | 7 | 3 | 0.5 | 0.49 |
| ApNi-4 | 8.34 | 15.77 | 1.85 | 6.55 | 1.37 | 0.46 | 1.19 | 0.26 | 1.04 | 0.28 | 0.63 | 0.20 | 0.70 | 0.24 | 1.8 | 4.4 | 33.9 | 0.10 | 57 | -- | 2.5 | 4.56 |
| ApNi-9 | 5.75 | 9.75 | 1.22 | 4.53 | 1.16 | 0.44 | 1.08 | 0.24 | 0.89 | 0.25 | 0.55 | 0.18 | 0.60 | 0.21 | 0.9 | 0.4 | 10.6 | 0.21 | 34 | -- | 1.0 | 0.96 |
| B16-25 | 0.87 | 1.70 | 0.20 | 0.88 | 0.26 | -- | 0.38 | 0.07 | 0.23 | 0.03 | 0.14 | 0.00 | 0.19 | 0.07 | 0.8 | 1.7 | 116.7 | 0.05 | 460 | -- | 0.3 | 0.48 |
| B16-27 | 4.73 | 8.15 | 1.37 | 4.75 | 1.23 | 0.54 | 1.32 | 0.52 | 1.14 | 0.48 | 0.72 | 0.41 | 0.73 | 0.37 | 1.1 | 6.3 | 24.8 | 0.16 | 156 | -- | 1.4 | 0.90 |
| B16-44 | 3.44 | 6.61 | 0.76 | 3.42 | 0.67 | 0.17 | 0.70 | 0.12 | 0.49 | 0.12 | 0.30 | 0.01 | 0.37 | 0.10 | 0.7 | 0.3 | 14.5 | 0.09 | 9 | -- | 0.8 | 0.43 |
| B16-46 | 4.23 | 8.44 | 0.96 | 4.07 | 0.90 | 0.20 | 0.79 | 0.12 | 0.55 | 0.10 | 0.36 | 0.05 | 0.41 | 0.10 | 0.8 | 1.7 | 11.3 | 0.12 | 82 | -- | 0.8 | 0.65 |
| B16-48 | 1.77 | 3.14 | 0.38 | 1.42 | 0.41 | 0.08 | 0.44 | 0.15 | 0.40 | 0.17 | 0.33 | 0.14 | 0.31 | 0.16 | 0.9 | 0.3 | -- | 0.12 | 1522 | -- | 0.6 | 0.51 |
| J70-11 | 5.84 | 9.83 | 1.21 | 4.60 | 0.99 | 0.28 | 1.09 | 0.25 | 0.96 | 0.27 | 0.61 | 0.20 | 0.63 | 0.21 | 1.0 | 2.6 | 32.0 | 0.09 | 1101 | -- | 1.5 | 1.74 |
| J70-14 | 20.52 | 34.65 | 4.84 | 18.01 | 3.39 | 0.54 | 2.41 | 0.44 | 1.74 | 0.43 | 1.09 | 0.25 | 0.97 | 0.26 | 3.7 | 1.7 | 20.9 | 0.02 | 91 | -- | 3.3 | 0.78 |
| J70-15 | 1.09 | 1.20 | 0.16 | 0.87 | 0.29 | 0.01 | 0.27 | 0.02 | 0.17 | 0.04 | 0.12 | -- | 0.21 | 0.06 | 0.0 | 0.2 | -- | 0.02 | 3 | -- | 0.2 | 0.17 |
| J70-18 | 3.49 | 6.80 | 0.76 | 3.22 | 0.79 | 0.14 | 0.80 | 0.09 | 0.59 | 0.09 | 0.27 | 0.01 | 0.41 | 0.09 | 0.7 | 4.7 | 9.5 | 0.07 | 174 | -- | 0.8 | 0.44 |
| J70-19 | 3.18 | 5.82 | 0.76 | 3.04 | 0.79 | 0.29 | 0.74 | 0.21 | 0.67 | 0.19 | 0.40 | 0.16 | 0.46 | 0.20 | 0.7 | 1.1 | 4.2 | 0.40 | 37 | 300 | 0.9 | 2.16 |
| J70-20 | 4.48 | 8.04 | 1.07 | 4.42 | 1.12 | 0.40 | 0.93 | 0.23 | 0.86 | 0.23 | 0.53 | 0.17 | 0.55 | 0.21 | 0.8 | 1.6 | 5.5 | 0.10 | 349 | 5 | 1.3 | 1.19 |
| J70-21 | 6.18 | 11.31 | 1.49 | 5.76 | 1.37 | 0.38 | 1.30 | 0.28 | 1.17 | 0.32 | 0.70 | 0.20 | 0.66 | 0.20 | 0.8 | 2.4 | 3.5 | 0.07 | 14 | -- | 1.4 | 1.05 |
| J70-23 | 5.25 | 8.52 | 0.92 | 3.63 | 0.82 | 0.23 | 0.93 | 0.15 | 0.66 | 0.19 | 0.37 | 0.10 | 0.47 | 0.14 | 0.7 | 0.3 | -- | 0.07 | 53 | -- | 0.7 | 0.60 |
| J70-26 | 4.12 | 6.61 | 0.78 | 2.98 | 0.81 | 0.33 | 0.79 | 0.21 | 0.71 | 0.24 | 0.46 | 0.16 | 0.55 | 0.21 | 0.7 | 0.3 | 3.0 | 0.14 | 65 | -- | 0.7 | 1.06 |
| Li35-8 | 9.20 | 17.46 | 2.15 | 7.40 | 1.64 | 0.55 | 1.44 | 0.29 | 1.16 | 0.28 | 0.60 | 0.18 | 0.63 | 0.22 | 1.4 | 0.9 | 1.1 | 0.09 | 215 | -- | 2.6 | 6.07 |
| Li35-9 | 7.25 | 13.94 | 1.76 | 6.51 | 1.43 | 0.52 | 1.12 | 0.25 | 0.89 | 0.23 | 0.49 | 0.17 | 0.54 | 0.20 | 1.2 | 2.5 | 1.8 | 0.10 | 35 | -- | 2.1 | 4.53 |
| TM-135 | 3.92 | 6.55 | 0.75 | 2.67 | 0.55 | 0.12 | 0.46 | 0.16 | 0.46 | 0.17 | 0.40 | 0.15 | 0.39 | 0.19 | 3.2 | 0.5 | -- | 0.02 | 377 | -- | 1.1 | 0.68 |
| TM-142 | 6.87 | 10.18 | 1.52 | 6.00 | 1.31 | 0.30 | 1.23 | 0.24 | 1.01 | 0.25 | 0.58 | 0.18 | 0.54 | 0.18 | 0.9 | 0.3 | 2.2 | 0.01 | 15 | -- | 1.6 | 9.99 |
| TM-150 | 3.49 | 6.35 | 0.81 | 3.27 | 0.70 | 0.23 | 0.70 | 0.22 | 0.70 | 0.20 | 0.45 | 0.16 | 0.41 | 0.18 | 0.8 | 0.7 | 5.2 | 0.10 | 9 | -- | 1.0 | 0.48 |
| TM-152 | 7.17 | 13.34 | 1.53 | 6.19 | 1.53 | 0.28 | 1.35 | 0.33 | 1.30 | 0.38 | 0.83 | 0.23 | 0.78 | 0.24 | 1.2 | 6.2 | 44.7 | 0.01 | 46 | 18 | 2.0 | 1.43 |
| TM-232 | 4.25 | 8.04 | 1.11 | 4.47 | 1.14 | 0.41 | 1.03 | 0.27 | 0.90 | 0.29 | 0.56 | 0.21 | 0.61 | 0.24 | 1.1 | 0.8 | 5.2 | 0.22 | 20 | -- | 1.3 | 0.42 |
| TM-300 | 4.13 | 7.72 | 1.13 | 4.73 | 1.24 | 0.35 | 1.22 | 0.28 | 0.88 | 0.27 | 0.58 | 0.17 | 0.52 | 0.19 | 0.8 | 1.4 | 42.1 | 0.10 | 11 | -- | 1.0 | 0.72 |
| TM-303 | 3.59 | 6.74 | 0.83 | 3.60 | 0.75 | 0.22 | 0.81 | 0.22 | 0.67 | 0.24 | 0.55 | 0.17 | 0.44 | 0.16 | 0.8 | 0.3 | -- | 0.01 | 2 | -- | 0.7 | 0.42 |
| TM-310 | 4.11 | 8.08 | 1.04 | 4.38 | 0.97 | 0.25 | 1.00 | 0.26 | 0.83 | 0.25 | 0.55 | 0.17 | 0.56 | 0.22 | 0.8 | 0.2 | 5.4 | 0.13 | 137 | 94 | 1.0 | 0.80 |
| TM-337 | 2.54 | 4.39 | 0.51 | 2.01 | 0.44 | 0.05 | 0.48 | 0.05 | 0.32 | 0.04 | 0.16 | -- | 0.29 | 0.06 | 0.4 | 1.1 | -- | 0.07 | 2028 | 9 | 0.6 | 0.33 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TM-360 | 3.25 | 6.05 | 0.84 | 3.22 | 0.81 | 0.31 | 0.80 | 0.20 | 0.74 | 0.21 | 0.41 | 0.16 | 0.48 | 0.20 | 1.2 | 0.7 | 5.9 | 0.09 | 24 | -- | 1.2 | 0.29 |
| TM-38 | 3.89 | 7.39 | 1.01 | 4.17 | 1.16 | 0.39 | 1.12 | 0.23 | 0.92 | 0.23 | 0.55 | 0.18 | 0.50 | 0.21 | 0.8 | 0.5 | 6.4 | 0.17 | 84 | -- | 0.9 | 0.71 |
| HO-3 | 6.92 | 12.65 | 1.43 | 5.31 | 1.02 | 0.02 | 0.84 | 0.05 | 0.93 | 0.04 | 0.45 | -- | 0.46 | 0.02 | 2.3 | 3.2 | 3.6 | 1.65 | 1711 | -- | 1.9 | 3.76 |
| LS-2 | 2.53 | 5.01 | 0.53 | 1.94 | 0.34 | -- | 0.33 | -- | 0.37 | -- | 0.09 | -- | 0.15 | -- | 2.1 | 0.1 | 2.9 | 0.14 | 20 | -- | 0.5 | 0.20 |
| MA-10 | 2.00 | 3.36 | 0.41 | 1.36 | 0.39 | 0.06 | 0.36 | 0.10 | 0.26 | 0.08 | 0.19 | 0.07 | 0.30 | 0.14 | 0.8 | 3.6 | -- | 0.17 | 1376 | -- | 0.7 | 0.72 |
| MA-2 | 5.98 | 11.80 | 1.35 | 5.31 | 1.08 | 0.04 | 0.74 | 0.04 | 0.58 | -- | 0.20 | -- | 0.18 | -- | 0.8 | 3.3 | 2.7 | 0.02 | 33 | -- | 1.5 | 6.59 |
| MA-4 | 5.37 | 9.03 | 1.29 | 5.40 | 1.29 | 0.67 | 1.52 | 0.31 | 1.28 | 0.34 | 0.93 | 0.21 | 0.67 | 0.21 | 0.8 | 0.3 | -- | 0.73 | 4484 | -- | 1.1 | 7.30 |
| MA-6 | 5.29 | 10.34 | 1.27 | 4.89 | 1.02 | 0.06 | 0.72 | 0.02 | 0.68 | -- | 0.26 | -- | 0.27 | -- | 1.7 | 7.2 | 5.9 | 0.21 | 1785 | -- | 1.6 | 4.72 |
| MA-7 | 5.38 | 11.69 | 1.41 | 6.01 | 1.26 | 0.08 | 0.97 | 0.10 | 0.93 | 0.05 | 0.37 | -- | 0.45 | -- | 0.7 | -- | 2.3 | 0.03 | 176 | -- | 1.2 | 6.49 |
| MA-9 | 0.98 | 0.96 | 0.15 | 0.77 | 0.23 | 0.01 | 0.29 | 0.06 | 0.18 | 0.06 | 0.14 | 0.02 | 0.20 | 0.08 | 0.0 | 2.1 | -- | 0.02 | 14 | -- | 0.2 | 0.25 |
| SJD-10 | 9.45 | 16.64 | 2.08 | 7.48 | 1.55 | 0.36 | 1.37 | 0.27 | 1.04 | 0.26 | 0.62 | 0.19 | 0.54 | 0.19 | 1.4 | 0.4 | -- | 0.03 | 8 | 7 | 2.2 | 5.30 |
| SJD-11 | 7.71 | 14.85 | 1.78 | 6.94 | 1.38 | 0.29 | 1.19 | 0.17 | 0.86 | 0.17 | 0.47 | 0.07 | 0.45 | 0.12 | 1.1 | 2.6 | -- | 0.03 | 138 | -- | 2.1 | 6.71 |
| SJD-12 | 9.30 | 16.36 | 2.00 | 7.47 | 1.46 | 0.37 | 1.31 | 0.29 | 0.99 | 0.26 | 0.62 | 0.17 | 0.56 | 0.19 | 1.4 | 1.3 | 3.9 | 0.02 | 9 | 9 | 2.2 | 5.41 |
| SJD-13 | 6.14 | 11.67 | 1.47 | 5.51 | 1.25 | 0.00 | 0.84 | 0.03 | 0.64 | -- | 0.24 | -- | 0.26 | -- | 0.9 | 3.3 | 1.1 | 0.01 | 544 | -- | 1.4 | 5.68 |
| SJD-14 | 7.54 | 14.28 | 1.72 | 6.59 | 1.49 | 0.29 | 1.12 | 0.18 | 0.80 | 0.16 | 0.42 | 0.06 | 0.44 | 0.12 | 1.1 | 3.8 | 77.4 | 0.04 | 214 | -- | 2.1 | 6.41 |
| SJD-15 | 5.76 | 11.24 | 1.26 | 4.57 | 0.95 | 0.15 | 0.91 | 0.14 | 0.69 | 0.16 | 0.47 | 0.07 | 0.49 | 0.12 | 0.8 | 5.0 | 2.1 | 0.02 | 38 | -- | 1.8 | 0.92 |
| SJD-19 | 7.39 | 13.57 | 1.61 | 5.98 | 1.20 | 0.30 | 0.99 | 0.24 | 0.74 | 0.22 | 0.48 | 0.17 | 0.45 | 0.17 | 0.9 | 1.0 | 1.2 | 0.02 | 26 | -- | 1.7 | 5.78 |
| SJD-2 | 5.37 | 9.64 | 1.15 | 4.32 | 0.73 | -- | 0.53 | -- | 0.55 | -- | 0.12 | -- | 0.16 | -- | 0.6 | -- | 14.8 | 0.02 | 14 | -- | 1.1 | 7.41 |
| SJD-20 | 0.70 | 1.49 | 0.10 | 0.52 | 0.16 | 0.00 | 0.22 | 0.04 | 0.14 | 0.03 | 0.07 | 0.02 | 0.14 | 0.07 | 0.0 | 9.2 | 34.9 | 0.03 | 3 | -- | 0.1 | 0.34 |
| SJD-21 | 5.82 | 11.62 | 1.23 | 4.84 | 1.01 | 0.19 | 0.96 | 0.16 | 0.83 | 0.15 | 0.42 | 0.07 | 0.44 | 0.11 | 0.9 | 5.4 | -- | 0.03 | 24 | -- | 1.8 | 0.93 |
| SJD-25 | 6.68 | 12.93 | 1.51 | 5.73 | 1.13 | 0.07 | 0.61 | 0.03 | 0.63 | -- | 0.14 | -- | 0.22 | -- | 0.8 | -- | -- | 0.04 | 6 | -- | 1.7 | 8.09 |
| SJD-5 | 17.75 | 32.07 | 3.70 | 14.24 | 2.79 | 0.60 | 2.40 | 0.50 | 2.33 | 0.59 | 1.48 | 0.31 | 1.41 | 0.34 | 4.7 | 1.5 | 19.1 | 0.01 | 385 | -- | 4.0 | 1.35 |
| SJD-7 | 7.58 | 14.65 | 1.75 | 6.43 | 1.39 | 0.10 | 0.87 | 0.03 | 0.77 | -- | 0.22 | -- | 0.32 | -- | 1.1 | 0.3 | 15.2 | 0.03 | 145 | -- | 1.9 | 6.33 |
| SJD-9 | 6.42 | 11.39 | 1.37 | 4.77 | 0.96 | 0.01 | 0.65 | 0.01 | 0.60 | -- | 0.16 | -- | 0.23 | -- | 0.7 | 2.3 | 1.5 | 0.03 | 6 | -- | 1.3 | 8.45 |
| SR-3 | 4.56 | 8.73 | 0.94 | 3.19 | 0.73 | 0.17 | 0.63 | 0.18 | 0.62 | 0.21 | 0.45 | 0.16 | 0.47 | 0.18 | 1.7 | 2.4 | 0.0 | 0.01 | 207 | -- | 1.1 | 2.31 |
| BCN-08 | 6.51 | 12.56 | 1.40 | 5.54 | 1.10 | 0.19 | 1.11 | 0.16 | 0.80 | 0.14 | 0.38 | 0.02 | 0.56 | 0.11 | 1.2 | 2.0 | 15.4 | 0.03 | 170 | -- | 1.9 | 0.39 |
| BCN-10 | 4.10 | 7.89 | 0.91 | 3.47 | 0.79 | 0.14 | 0.78 | 0.09 | 0.63 | 0.09 | 0.32 | 0.01 | 0.33 | 0.08 | 0.7 | 0.9 | -- | 0.02 | 191 | -- | 1.3 | 0.36 |
| BCN-11 | 9.97 | 19.36 | 2.22 | 8.95 | 1.69 | 0.29 | 1.58 | 0.22 | 1.43 | 0.24 | 0.73 | 0.07 | 0.84 | 0.14 | 1.4 | 0.3 | -- | 0.03 | 158 | -- | 3.0 | 0.77 |
| BCN-12 | 5.72 | 11.40 | 1.37 | 5.45 | 1.38 | 0.13 | 1.24 | 0.14 | 0.81 | 0.13 | 0.44 | 0.04 | 0.53 | 0.10 | 1.0 | 0.3 | -- | 0.04 | 1009 | 6 | 2.2 | 0.77 |
| BCN-13 | 11.27 | 21.96 | 2.60 | 9.78 | 1.97 | 0.35 | 1.80 | 0.27 | 1.53 | 0.31 | 0.88 | 0.09 | 1.00 | 0.17 | 2.1 | 0.4 | -- | 0.03 | 93 | -- | 4.2 | 1.03 |
| BCN-14 | 13.10 | 25.06 | 2.93 | 11.41 | 2.33 | 0.44 | 2.17 | 0.42 | 1.83 | 0.46 | 1.17 | 0.27 | 1.13 | 0.28 | 3.4 | 1.6 | 17.8 | 0.00 | 121 | -- | 4.2 | 1.06 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BCN-15 | 13.17 | 25.13 | 2.91 | 11.26 | 2.35 | 0.44 | 2.00 | 0.40 | 1.85 | 0.47 | 1.07 | 0.27 | 1.08 | 0.28 | 3.2 | 1.0 | 31.3 | 0.00 | 124 | -- | 4.3 | 1.04 |
| BCN-17 | 4.24 | 7.74 | 0.97 | 3.78 | 0.84 | 0.17 | 0.83 | 0.23 | 0.75 | 0.24 | 0.55 | 0.17 | 0.53 | 0.19 | 0.9 | 2.1 | 15.6 | 0.01 | 88 | -- | 1.3 | 0.38 |
| BCN-18 | 6.53 | 12.53 | 1.54 | 5.50 | 1.21 | 0.30 | 1.16 | 0.31 | 1.08 | 0.35 | 0.75 | 0.23 | 0.67 | 0.22 | 1.3 | 5.8 | 489.9 | 0.03 | 1584 | -- | 2.1 | 0.57 |
| BCN-2 | 9.27 | 18.49 | 2.26 | 8.59 | 1.99 | 0.39 | 1.63 | 0.33 | 1.45 | 0.37 | 0.89 | 0.22 | 0.75 | 0.24 | 1.8 | 1.5 | -- | -- | 509 | 2 | 3.0 | 0.81 |
| BCN-20 | 10.22 | 19.47 | 2.27 | 8.67 | 1.79 | 0.38 | 1.77 | 0.34 | 1.60 | 0.38 | 0.91 | 0.25 | 0.93 | 0.28 | 1.9 | 0.4 | 19.4 | 0.02 | 189 | -- | 3.1 | 1.59 |
| BCN-22 | 8.77 | 16.95 | 2.04 | 7.68 | 1.78 | 0.22 | 1.66 | 0.23 | 1.28 | 0.24 | 0.72 | 0.06 | 0.73 | 0.13 | 1.7 | 2.4 | 0.5 | 0.02 | 791 | 3 | 3.2 | 0.95 |
| BCN-23 | 13.60 | 26.37 | 3.11 | 12.02 | 2.65 | 0.39 | 2.01 | 0.29 | 1.91 | 0.34 | 1.14 | 0.12 | 1.07 | 0.20 | 3.4 | 0.6 | -- | 0.04 | 147 | -- | 4.6 | 1.14 |
| BCN-24 | 3.66 | 7.23 | 0.81 | 3.45 | 0.52 | 0.06 | 0.63 | 0.09 | 0.43 | 0.06 | 0.28 | 0.00 | 0.30 | 0.08 | 0.7 | 0.2 | -- | 0.03 | 196 | -- | 1.2 | 0.45 |
| BCN-25 | 3.78 | 7.50 | 0.86 | 3.14 | 0.76 | 0.08 | 0.61 | 0.09 | 0.42 | 0.06 | 0.23 | -- | 0.30 | 0.07 | 0.6 | 0.6 | -- | 0.02 | 132 | -- | 1.2 | 0.35 |
| BCN-3 | 13.69 | 26.74 | 3.10 | 11.63 | 2.57 | 0.55 | 2.09 | 0.42 | 2.00 | 0.47 | 1.18 | 0.26 | 1.16 | 0.27 | 2.1 | 0.6 | 5.4 | -- | 82 | -- | 4.5 | 1.44 |
| BCN-4 | 6.17 | 11.48 | 1.45 | 5.48 | 1.41 | 0.29 | 1.09 | 0.25 | 0.98 | 0.26 | 0.59 | 0.19 | 0.57 | 0.19 | 1.2 | 0.6 | -- | 0.03 | 253 | 15 | 2.3 | 0.75 |
| BCN-5 | 7.11 | 13.81 | 1.65 | 6.27 | 1.50 | 0.35 | 1.37 | 0.31 | 1.34 | 0.38 | 0.76 | 0.21 | 0.77 | 0.22 | 1.1 | 1.6 | -- | -- | 4681 | -- | 2.1 | 0.63 |
| BCN-6 | 14.19 | 28.14 | 3.31 | 12.37 | 2.70 | 0.48 | 2.14 | 0.44 | 2.00 | 0.50 | 1.23 | 0.27 | 1.16 | 0.28 | 2.7 | 0.6 | -- | 0.00 | 255 | -- | 4.6 | 1.51 |
| BCN-7 | 3.54 | 6.73 | 0.81 | 3.33 | 0.88 | 0.20 | 0.74 | 0.19 | 0.72 | 0.23 | 0.43 | 0.16 | 0.47 | 0.18 | 0.8 | 0.3 | -- | -- | 1588 | 2 | 1.3 | 0.38 |
| SBG-1 | 15.94 | 31.47 | 3.56 | 13.70 | 2.76 | 0.36 | 2.28 | 0.27 | 1.97 | 0.29 | 1.05 | 0.06 | 1.09 | 0.11 | 2.4 | -- | 5.2 | 0.03 | 161 | -- | 4.8 | 1.48 |
| SBG-10d | 12.85 | 25.16 | 2.88 | 10.78 | 2.24 | 0.19 | 1.66 | 0.19 | 1.55 | 0.18 | 0.83 | 0.03 | 0.87 | 0.04 | 3.2 | -- | 6.0 | 0.02 | 934 | -- | 4.0 | 1.15 |
| SBG-10e | 8.19 | 16.00 | 1.92 | 6.91 | 1.38 | 0.03 | 1.19 | 0.12 | 1.07 | 0.09 | 0.56 | -- | 0.52 | -- | 1.4 | -- | -- | 0.01 | 203 | -- | 2.5 | 1.60 |
| SBG-10f | 16.29 | 32.13 | 3.81 | 14.32 | 2.70 | 0.32 | 2.34 | 0.28 | 1.95 | 0.26 | 1.01 | 0.06 | 0.91 | 0.10 | 2.4 | -- | 11.2 | 0.05 | 253 | -- | 4.6 | 1.60 |
| SBG-2 | 7.78 | 15.02 | 1.68 | 6.63 | 1.40 | 0.01 | 1.04 | 0.07 | 1.06 | 0.07 | 0.38 | -- | 0.42 | -- | 1.2 | -- | 17.5 | 0.03 | 1647 | 13 | 2.2 | 0.76 |
| SBG-20a | 3.66 | 6.51 | 0.77 | 3.35 | 0.49 | -- | 0.39 | -- | 0.38 | -- | 0.14 | -- | 0.17 | -- | 0.5 | -- | -- | 0.08 | 429 | 1203 | 1.0 | 0.27 |
| SBG-20b | 6.03 | 11.66 | 1.37 | 5.12 | 1.00 | -- | 0.79 | 0.06 | 0.74 | -- | 0.34 | -- | 0.33 | -- | 0.9 | -- | 0.6 | 0.01 | 1908 | -- | 1.7 | 0.85 |
| SBG-20f | 13.41 | 26.70 | 3.02 | 11.58 | 2.36 | 0.44 | 2.25 | 0.31 | 1.79 | 0.35 | 0.94 | 0.12 | 0.92 | 0.16 | 2.2 | 2.0 | 18.1 | 0.03 | 108 | -- | 4.3 | 1.69 |
| ApNi-8 | 4.37 | 8.69 | 1.19 | 4.82 | 1.10 | 0.32 | 1.26 | 0.18 | 0.85 | 0.19 | 0.53 | 0.06 | 0.45 | 0.06 | 0.7 | 1.5 | 26.9 | 0.05 | 50 | -- | 1.0 | 1.08 |
| J70-13 | 2.69 | 4.59 | 0.62 | 2.45 | 0.46 | 0.15 | 0.67 | 0.17 | 0.49 | 0.12 | 0.26 | 0.08 | 0.29 | 0.13 | 0.4 | 2.3 | 4.6 | 0.04 | 353 | -- | 0.7 | 0.38 |
| Li35-7 | 2.11 | 4.11 | 0.49 | 1.80 | 0.30 | 0.06 | 0.44 | 0.07 | 0.30 | 0.08 | 0.20 | 0.04 | 0.29 | 0.06 | 4.0 | 1.6 | 2.8 | 0.01 | 4 | -- | 0.7 | 0.29 |
| Li35-3 | 14.48 | 27.25 | 3.30 | 12.36 | 2.52 | 0.57 | 2.13 | 0.31 | 1.71 | 0.34 | 0.86 | 0.12 | 0.93 | 0.15 | 1.6 | 1.9 | 35.0 | 0.07 | 30 | -- | 4.3 | 3.06 |
| J70-2 | 10.73 | 20.49 | 2.32 | 8.55 | 1.76 | 0.33 | 1.52 | 0.25 | 1.33 | 0.28 | 0.79 | 0.13 | 0.92 | 0.13 | 3.9 | 4.3 | 10.3 | 0.02 | 195 | -- | 3.1 | 1.37 |
| J70-32 | 8.84 | 17.39 | 2.08 | 7.53 | 1.60 | 0.35 | 1.37 | 0.22 | 1.00 | 0.26 | 0.59 | 0.10 | 0.69 | 0.12 | 1.8 | 18.0 | 9.3 | 0.02 | 53 | -- | 2.2 | 1.63 |
| J70-35 | 14.95 | 29.66 | 3.47 | 13.28 | 2.76 | 0.53 | 2.34 | 0.34 | 2.09 | 0.44 | 1.18 | 0.19 | 1.26 | 0.19 | 5.0 | 1.9 | 17.6 | 0.04 | 126 | -- | 4.2 | 2.29 |
| J70-44 | 15.72 | 29.47 | 3.41 | 12.92 | 2.37 | 0.49 | 2.18 | 0.33 | 1.92 | 0.40 | 1.03 | 0.13 | 1.07 | 0.17 | 2.9 | 1.6 | 1.3 | 0.03 | 581 | -- | 4.6 | 1.89 |
| J70-46 | 13.08 | 24.26 | 2.89 | 10.75 | 1.97 | 0.42 | 1.84 | 0.28 | 1.64 | 0.34 | 0.90 | 0.11 | 0.93 | 0.14 | 2.6 | 4.5 | 2.8 | 0.03 | 662 | -- | 3.6 | 1.78 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J70-40 | 17.14 | 33.04 | 3.98 | 15.56 | 3.28 | 0.74 | 3.12 | 0.46 | 2.47 | 0.50 | 1.55 | 0.20 | 1.41 | 0.22 | 3.0 | 5.1 | 10.5 | 0.01 | 87 | -- | 3.8 | 3.87 |
| Li35-5 | 13.95 | 26.07 | 3.10 | 10.62 | 2.29 | 0.43 | 1.88 | 0.29 | 1.76 | 0.34 | 0.87 | 0.11 | 1.01 | 0.15 | 2.7 | 0.9 | 2.3 | 0.02 | 512 | -- | 3.8 | 1.75 |
| Li35-4 | 13.16 | 26.19 | 3.12 | 11.10 | 2.16 | 0.55 | 2.05 | 0.27 | 1.56 | 0.33 | 0.90 | 0.13 | 1.01 | 0.13 | 1.5 | 0.9 | 3.5 | 0.04 | 17 | -- | 4.1 | 2.16 |
| MA-8 | 2.46 | 4.95 | 0.65 | 2.43 | 0.48 | 0.11 | 0.45 | 0.15 | 0.38 | 0.16 | 0.30 | 0.14 | 0.25 | 0.16 | 0.9 | 0.5 | -- | 0.11 | 40 | -- | 0.6 | 0.39 |

APPENDIX 3. PEOPLE INVOLVED IN THE GLASS INDUSTRY IN MEXICO CITY

| **Century** | **Year(s)** | **Name** | **Place of Origin** | **Occupation** | **Notes** | **Reference** |
|---|---|---|---|---|---|---|
| 16th century | 1533 | Rodrigo Despinosa | Guadahortuña, Granada, Spain | Vidriero (glassmaker) | Married, but his wife is not with him | Paso y Troncoso 1940: 151 |
| | 1539 | Vergara | | Unknown | He was paid for the materials and mounting of the windows of the cathedral. Uncertain if he was a glass artisan | Martins Torres 2019b: 124 (table 10) |
| | 1557 | Juan Rodríguez | Seville, Spain (previously Coria, Extremadura) | Maestro vidriero (master glassmaker) | He gets permission to take with him two glass helpers (oficiales), his wife and single children | AGI, Indiferente, 1965, L.13, f. 386v-387 Martins Torres 2019b: 124 (table 10) |
| | 1560 | Hernando de Espinosa | Spain | vidriero | Travelled to New Spain in 1560 with his servant Pedro Peinado | Romera and Galbis1980: 20 |
| | 1560 | Guillén del Más (de Almas) | Catalonia, Spain | Vidriero (glassmaker) | Obtained permission to build a portal in front of the houses where he lives that leads to the market of San Juan, outside of the *traza.* | O'Gorman 1970: 367 |
| | 1562 | Guillén de Almas | Catalonia, Spain | Vidriero (glassmaker) | The Cabildo of Mexico City grants him a *pedazo de solar* or iece of land on May 29, 1562. He was married to an indigenous woman who was the owner of the house where they lived in the barrio of the market of San Juan | O'Gorman 1970: 385 Peralta Rodríguez 2018: 24 Boehm de Lameiras 1987: 27 |
| | 1563 | Pedro del Huerto | Seville, Spain | Vidriero (glassmaker) | He requests permission to return to Mexico City after traveling to Castile to get tools, and to take back with him two glass helpers (officials) | AGI, Indiferente, 2052, N.34, f. 1-17 |
| | 1566 | Guillen de Almas | | Oficial de hazer vidros (officer of glassmaking) | He requests permission to travel to Peru to buy colorants and tools that arrived there from Castile (February) | Fernández 1990: 49 |

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|---|---|---|---|---|---|---|
| | 1566 | Guillén de Almaz (Almas) | Catalonia, Spain | Vidriero (glassmaker) | Self-denounce for not letting some women take from him some glasses he had that said: “Pese a Dios” (despite God) | AGN, Indiferente Virreinal, caja 5463, exp.58, f. 1. |
| | 1566 | Pedro Peinado | Ladrada (La Adrada), Ávila | Vidriero? (glassmaker?) | Partner of Guillén de Almas Travelled to New Spain on January 5th, 1560 as the servant of Hernando de Espinosa, glassmaker. Pedro Peinado was born in Ladrada, single, son of Francisco Peinado and María López | Fernández 1990: 49 Romera y Galbis 1980: 20 |
| | 1571 | Miguel del Huerto | | Vidriero (glassmaker) | | Sánchez Arreola y Zárate 2015: 151 [0219] Fernández 1990: 258 AGN, Inquisición, vol. 91, exp. 5, f. 76v AGN, Reales Cédulas Duplicadas, vol. III, exp. 162, f.122 |
| | 1571 | Mateo del Huerto | | Vidriero (glassmaker) | | Fernández 1990: 258 AGN, Reales Cédulas Duplicadas, vol. III, exp. 162, f.122 |
| | 1571 | Pedro del Huerto | | Vidriero (glassmaker) | | Sánchez Arreola y Zárate 2015: 151 AGN, Inquisición, vol. 91, exp. 5, f. 76v |
| | 1571 | Joan de Espinosa | Seville, Spain | Vidriero (glassmaker) | 33 years old | Sánchez Arreola y Zárate 2015: 151 AGN, Inquisición, vol. 91, exp. 5, f. 98 |
| | 1580 | Mateo Ruiz | | Vidriero (glassmaker) | Lives in the *barrio* of San Juan | Maldonado Mares y Pineda Mendoza 1995:194 |
| | 1596 | Xaime del Valle | Catalonia, Spain | Vidriero (glassmaker) | … makes Works of glass with much beauty and perfection, an better and clearer unlike anything made so far by other glassmakers in the city (Mexico City), so much that it is posible to pass this | Fernández 1990: 228; AGN, Reales Cédulas Duplicadas vol. 3, exp. 161, fs. 120v-122 |

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|---|---|---|---|---|---|---|
| | | | | | tepublic without need of that from Venice or other lands… (Oct.10 1596) | |
| | 1596 | Miguel del Huerto | | Vidriero (glassmaker) | | Fernández 1990: 59 AGN, Reales Cédulas Duplicadas, vol. III, exp. 162, f.122 |
| | 1596 | Mateo del Huerto | | Vidriero (glassmaker) | | Fernández 1990: 59 AGN, Reales Cédulas Duplicadas, vol. III, exp. 162, f.122 AGN, Inquisición, Vol. 91, exp. 5, f. 76v. |
| | 1596 | Juan de Quiroz | | Vidriero (glassmaker) | | AGN, Indiferente Virreinal, Caja 5990, Exp. 38, f.1 |
| | 1596 | Blas Hernández | Castille | Vidriero (glassmaker) | Lives in the house of Cristóbal Manuel in Portal Nuevo | AGN, Indiferente Virreinal, caja 5990, exp. 38, f.1 |
| $17^{th}$ century | 1600 | Miguel López del Huerto | | Vidriero (glassmaker) | Lives in the Street that goes from San Agustín to the hermit of Nuestra Señora de Monserrat, property of Francisca Contreras | Zárate Sánchez 2004: 25 AHNCM,[297] Protocolos, vol.3357, f.219 |
| | 1603 | Xaime del Valle | | Vidriero (glassmaker) | Requests permission to move to Peru because he is in need and take with him four Spanish men: Francisco Roche, Esteban Roche, Francisco, and Joan de Guevara, his slave, as well as Simón and Joan de Roses, black slaves | AGN, Indiferente virreinal, caja 0589, exp. 10, f.1. |
| | 1605 | Juan Bautista Nieto | | Vidriero (glassmaker) | | Zárate Sánchez 2004: 50 AHNCM, Protocolos, vol.3363, f.988 |
| | 1612 | Juan de Quiroz | | Maestro labrador de vidrios (Master of glass carving) | Received in credit María Magdalena, Indian, locked in the public jail | Zárate Sánchez 2004: 29 AHNCM, Protocolos, Vol.3359, f.50 |

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|---|---|---|---|---|---|---|
| | 1612 | Juan de Quiroz | | Maestro de cortar vidrio (Master glass cutter) | 60 years old. Lives in the Calle de la Acequia | Maldonado Mares 1995: 84<br>AGN, Matrimonios, vol. 98. exp. 112, f. 299 |
| | 1617 | Blas Hernández | | Maestro de hazer vidrio (Master glassmaker) | Makes glass for the retorts used in gold-parting | Fernández 1990: 230, 258<br>AGN, Ordenanzas, vol.3, f.38-39v |
| | 1617 | Francisco Prieto | | Maestro de hazer vidrio (Master glassmaker) | Makes glass for the retorts used in gold-parting | Fernández 1990: 230, 258<br>AGN, Ordenanzas, vol.3, exp. 162, f.122 |
| | 1617 | Joan de Mora | | Maestro de hazer vidrio (Master glassmaker) | Makes glass for the retorts used in gold-parting | Fernández 1990: 230, 258 (AGNM, Ordenanzas, vol.3, exp. 162, f.122) |
| | 1626 | Tomás Franco | | Vidriero (glassmaker) | Rents a house in the *barrio* of La Trinidad for four years | Pineda Mendoza y Zárate Sánchez 2005: 26<br>AHNCM, Protocolos, Libro 8, f.93 |
| | 1628 | Hernando Ramírez | Veracruz | Oficial de vidriero (officer glassmaker) | Black, 54 years old, resident in the *barrio* del Carmen where he Works with the master Joan de Mora | López Reyes 1985: 5<br>AGN Matrimonios, vol. 48, exp. 94, f.251v |
| | 1629 | Luis de Villagrán | | Vidriero (glassmaker) | Spanish, 23 years old, lives in the *barrio* of Santa Cruz | López Reyes 1985: 71<br>AGN Matrimonios, vol. 64, exp. 137, f.411v |
| | 1629 | Francisco Gutiérrez | | Oficial de cuentas de vidrio (officer of glass beads) | Spanish, 30 años, resident in the barrio of San Lazaro | López Reyes 1985: 72<br>AGN Matrimonios, vol. 64, exp. 137, f. 412 |
| | 1629 | Francisco Lara | | Oficial de hacer cuentas de vidrio y otras cosas (officer of glass beads and other things) | 26 years old | Fernández 1990: 258<br>Martins Torres 2019b: 128 (table 12) |
| | 1629 | Pedro de Cárdenas | | Oficial de vidriero del candil (Officer lampworker) | Spanish, married, 29 years old, Works in the store of Laçaro de Espinosa, lives in Puente de San Laçaro | Martins Torres 2019b: 128 (table 12) |

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|---|---|---|---|---|---|---|
| | | | | | | AGN Matrimonios, Vol. 113, exp.106, f. 269v-270 |
| | 1629 | Sebastián Ortiz | | Maestro vidriero (Master glassmaker) | 30 years old | Martins Torres 2019b: 131 (table 15) |
| | 1632 | Gerónimo Porrata | | Trabajador en horno de vidrio (worker in a glass furnace) | Spanish, acused of having a stolen mule | Martins Torres 2019b: 131 (table 15)<br>AGN, Procesos Civiles, vol.16, exp. 31. |
| | 1633 | Juan Ponce | | Vidriero (glassmaker) | Spanish, 28 años, Barrio de la Merced | Martins Torres 2019b: 131 (table 15) |
| | 1633-40 | Riviera | | Maestro Vidriero de Candil (Master lampworker) | Hired a 12-year-old mestizo servant girl for four years | Mentz 1999: 153, 156<br>AHNCM, José Vedor, vol. 4595, f.687 |
| | 1635 | Juan de Cázares | | Vidriero (glassmaker) | Mulato free of captivity, 24 years old, lives in the *barrio* of San Pablo in the house of Marcos de Cazares, his father | Martins Torres 2019b: 131 (table 15)<br>AGN Matrimonios, vol. 36, exp.57, f. 215v |
| | 1636 | Josephe de León | | Oficial de vidriero del candil (officer lampworker) | Spanish, 21 years old, Works in the house of German de Roxas, in the barrio de Santa Cruz | AGN Matrimonios, vol. 183, exp.26, f.2v-3 |
| | 1636 | Francisco Prieto | | Tratante de vidrios (glass merchant) | | Pineda Mendoza y Zárate Sánchez 2005: 83<br>AHNCM, Protocolos, vol. 2481, f.103 |
| | 1636 | Germán de Rojas | | Maestro vidriero (Master glassmaker) | Barrio de Santa Cruz | Martins Torres 2019b: 131 (table 15) |
| | 1640 | Francisco Leonardo de la Vandera | Seville | Vidriero (glassmaker) | Spanish, 27 years old, neighbor of the barrio de San Gregorio, died in 1685 | Martins Torres 2019b: 131 (table 15)<br>AGN Matrimonios, Vol. 126, exp.38, f. 116 |
| | 1640 | Juan de Ávila | | Vidriero (glassmaker) | Spanish, 40 years old, neighbor of the barrio de Santa Cruz<br>Master glassmaker one year later | Martins Torres 2019b: 131 (table 15)<br>AGN Matrimonios, vol. 126, exp.86, f. 243v |

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|---|---|---|---|---|---|---|
| | 1640 | Pedro de Cárdenas | | Oficial de vidriero de candil (oficer lampworker) | Spanish, 40 years old, neighbor of the barrio de la Santísima Trinidad | AGN Matrimonios, vol. 132, exp.9, f. 2v |
| | 1640 | Diego García de Gándara | | Oficial de hacer cuentas de vidrio (officer of glass beads) | | Maldonado Mares y Pineda 1995<br>AGN, Matrimonios, vol. 126, exp. 37, f.113 |
| | 1640 | Alonso Franco Hidalgo | | Vidriero de hacer cuentas de vidrio (glassmaker of glass beads) | Spanish, 25 years old | Martins Torres 2019b: 128 (table 12) |
| | 1640 | Juan de Espinosa | | Veedor de vidrieros de candil (supervisor of lampworking) | | Bejarano 1910: 45<br>Martins Torres 2019b: 131 (table 15) |
| | 1641 | Juan de Ávila | | Maestro de vidriero (master glassmaker) | Spanish, lives in the barrio de Santa Cruz | AGN Matrimonios, vol. 138, exp.26, f. 1v |
| | 1641 | Diego Maldonado | | Oficial de vidriero | Spanish, vive al barrio de Santa Cruz | AGN Matrimonios, vol. 138, exp.26, f. 1v |
| | 1642 | Diego Becerra | | Maestro vidriero del candil (master lampworker) | | Pineda Mendoza y Zárate Sánchez 2005: 29<br>AHNCM, Protocolos, Libro 9, f.440v-441 |
| | 1646 | Melchor de Solís | | Oficial de vidriero (officer glassmaker) | 28 years old, neighbor of the barrio de Nuestra Señora de la Merced | AGN Matrimonios, vol. 172, exp.93, f. 1v |
| | 1647 | Alonso de Dueñas | | Vidriero | Spanishl, 30 years old, neighbor of the barrio de Santa Cruz where he has a *cindil de bidriero* (?) | Martins Torres 2019b: 132 (table 15)<br>AGN Matrimonios, vol. 206, exp.6, f. 1v |
| | 1649 | Bernardo Ramírez | | Aprendíz de vidriero (apprentice glassmaker) | Spanish, 18 years old, lives inside the hospital of San Lázaro with Diego de Patel<br>Apprentice of the master Diego de Pascual | Martins Torres 2019b: 132 (table 15)<br>AGN Matrimonios, vol. 75, exp.124, f. 467v |
| | 1649 | Diego de Pascual (Patel/Patse) | | Maestro vidriero (master glassmaker) | Lives in the hospital of San Lázaro, teaches the craft to Bernardo Ramírez | Martins Torres 2019b: 132 (table 15) |

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|---|---|---|---|---|---|---|
| | | | | | | AGN Matrimonios, vol. 75, exp.124, f. 467v |
| | 1652 | Claudio Francisco Troncoso | Borgoña | Maestro vidriero, maestro de hacer anteojos, cosas de vidrio y carey (master glassmaker, master of making ophthalmic glasses, glass and tortoiseshell things | Calle Real del Palacio | Fernández 1990: 258<br>Martins Torres 2019b: 132 (table 15) |
| | 1663 | Juan Ponce | | Vidriero (glassmaker) | Spanish, 28 years old, barrio de la Merced where he works | AGN Matrimonios, Vol. 173, exp.30, f. 2 |
| | 1664 | Matheo Gomez | | Vidriero y carpintero (glassmaker and carpenter) | Spanish, lives in Mexico City in the Street named "del Candil al barrio de la Santísima Trinidad." | González Franco et al 1986: 46; 1994: 178.<br>Martins Torres 2019b: 130 (table 14) |
| | 1664 | Bartolomé de Mora | | Vidriero (glassmaker) | Guarantor of the altarpiece of the church of la Merced | Martins Torres 2019b: 132 (table 15) |
| | 1671 | Claudio Francisco | | Maestro de hacer vidrieras (master of stained glass windows) | Agrees to make nine glass windows for the church of Nuestra Señora de Valvanera. Received 900 pesos from the steward of the convent of Valvanera and the master architect Rodrigo Díaz de Aguilera, for making the stained glass windows for the convent's church | Pineda Mendoza 2010: 23<br>Martins Torres 2019b: 132 (table 15)<br>AHNCM, Protocolos, Libro 15, f. 258v-260; f.390 |
| | 1671 | Mateo de Chavez | | Maestro de hacer vidrieras (master of stained glass windows) | Agrees to make nine glass windows for the church of Nuestra Señora de Valvanera. Received 900 pesos from the steward of the convent of Valvanera and the master architect Rodrigo Díaz de Aguilera, for making the stained glass windows for the convent's church | Pineda Mendoza 2010: 23<br>Martins Torres 2019b: 132 (table 15)<br>AHNCM, Protocolos, Libro 15, f. 258v-260; f.390 |
| | 1672 | Juan Franco | | Vidriero (glassmaker) | 50 years old, lives in the barrio de la Santísima Trinidad | AGN Matrimonios, vol. 29, exp.10, f. 24v |

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| | 1672 | Francisco de Vega | | Vidriero del candil (lampworker) | 60 years old, lives in barrio de San Pablo | Martins Torres 2019b: 128 (tabla 12)<br>AGN Matrimonios, vol. 111, exp. 8, f. 105v |
| | 1672 | Tomás de León | Mexico | Oficial de vidriero del candil (officer lampworker) | 37 years old | Martins Torres 2019b: 12 (tabla 12)<br>AGN Matrimonios, Vol. 111, exp.28, f. 149v |
| | 1672 | Francisco de Ugarte | Mexico | Vidriero del candil (lampworker) | 55 years old, lives in the barrio de San Pablo | Martins Torres 2019b: 128-129 (tabla 12)AGN Matrimonios, Vol. 111, exp.28, f. 150 |
| | 1672 | Agustín Baptista | | Vidriero del candil (lampworker) | 38 years old | Martins Torres 2019b: 129 (tabla 12)AGN, Matrimonios, vol.122, exp.130 |
| | 1673 | Juan Bautista Tiburcio | Franco, Borgoña | Vidriero de anteojos (ophtalmic glasses maker) | In the Empedradillo | Martins Torres 2019b: 132 (tabla 15)<br>Rubio Mañé 1966: 216 |
| | 1675 | Tomás Franco | | Maestro vidriero (master glassmaker) | | Pineda Mendoza 2010: 39<br>AHNCM, Protocolos, Libro 19, f. 283 |
| | 1677 | Claudio Francisco | | Maestro vidriero (master glassmaker) | Issued a receipt for 500 pesos to the bachelor Felipe de Contreras, steward of the Congregación del Señor San Pedro licated in the church of La Santísima Trinidad, for the making of eight Castillian stained glass windows with wire grids for the church | Pineda Mendoza 2010: 50<br>AHNCM, Protocolos, Libro 21, f. 314v-315 |
| | 1680 | Antonio López | | Oficial vidriero (officer glassmaker) | 48 years old, resident in the Plazuela de las Gallas | López Reyes 1985: 88<br>AGN Matrimonios, Vol. 67, exp. 85, f.350 |
| | 1680 | Diego de Ávila | | Oficial de vidriero (officer glassmaker) | Barrio de Santa Madalena | Martins Torres 2019b: 131 (table 15) |

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| | 1681 | Francisco Durán | | Vidriero de Candil (lampworker) | 40 years old, lives in the Portal de las Flores (by the Acequia Real) | López Reyes 1985: 21<br>AGN Matrimonios, vol. 53, exp. 17, f. 197v |
| | 1681 | Pedro de Mora Esquibel | | Maestro de Vidriero (master glassmaker) | Mulato free of captivity, 50 years old | AGN ,Matrimonios, vol. 166, exp.44, f. 1v<br>Martins Torres 2019b: 133 (table 15) |
| | 1682 | Juan Franco | | Maestro Vidriero (master glassmaker) | Spanish, 60 years old | AGN Matrimonios, vol. 98, exp.59, f. 150-152v |
| | 1682 | Juan de Frias | | Oficial de vidriero (officer glassmaker) | Spanish, 25 years old | Martins Torres 2019b: 133 (table 15)<br>AGN Matrimonios, vol. 137, exp.64, f. 1v |
| | 1682 | Diego de Ávila | | Oficial de vidriero (officer glassmaker) | Mestizo (?), 53 years old, in the barrio de la Almeda | AGN Matrimonios, vol. 138, exp.70, f. 11v |
| | 1689 | Tomás de Lizarra | San Sebastián, Vizcaya | Vidriero de oficio (glassmaker) | Spanish, single, Calle de San Agustín that begins from the back of the Hospital Real and continues straight by the Convent of Balvanera until the bridge of the false door of La Merced | Martins Torres 2019b: 133 (table 15)<br>Rubio Mañé 1966: 90 |
| | 1689 | Claudio Francisco | Borgoña | Maestro de Vidriero (master glassmaker) | Widow, vassal of the King of Spain, more tan 60 years old, with family | Rubio de Mañé 1966: 173 |
| | 1689 | Tomás Franco | | Glass furnace owner | | Rubio de Mañé 1966: 133 |
| | 1693 | Simón de Aguilar | | Labrador de vidrios (glass carver) | | Martins Torres 2019b: 133 (table 15) |
| | 1698 | Miguel Claudio | | Vidriero (glassmaker) | Made the glass for the Palacio Real | Martins Torres 2019b: 133-134 (table 15) |
| 18th Century | 1704 | Jerónimo Jhirordi | | Maestro vidriero (master glassmaker) | Appointed appraiser of merchandise to list and appraise the mirrors that were part of the possessions of the Capitan Nicolás de Arteaga | González Franco et al 1986: 55; 1994: 419. |

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| | 1706 | Nicolás Fijón | | Oficial de vidriero (officer glassmaker) | Spanish, 34 years old, worked in the barrio de la Santísima Trinidad | López Reyes 1985: 135 AGN, Matrimonios, vol. 76, exp. 79, f.274v |
| | 1706 | José Gómez Villegas | | Vidriero (glassmaker) | Worked in the barrio de la Santísima Trinidad | López Reyes 1985: 135 AGN Matrimonios, vol. 76, exp. 79, f.274 |
| | 1706 | Andrés de Monroy | | Vidriero (glassmaker) | Spanish, 29 years old, glassmaker but does not practice it and lives in the street of the Hospital del Amor de Dios in the houses of Don Francisco de Orduña. He was in the Port of Cavite in the Philippines (Manila) from where he came back four years ago | AGN, Matrimonios, vol. 96, exp.64, f. 306v |
| | 1717-30 | Marcos Joseph de Estrada | | | | Fernández 1990: 259 |
| | 1718 | Juan de Solís | | Maestro de candil y vidriero (lampworker and glassmaker) | Mestizo, 34 years old, resident in the street of La Santísima Trinidad | López Reyes 1985: 107 AGN, Matrimonios, vol. 72, exp. 5, f.51 |
| | 1719 | Francisco Xavier de la Fuente | | Asistente en horno de vidrio (helper in a glass furnace) | Single, 20 years old, lives in barrio de San Lázaro. Works in the glass furnace of Antonio Franco | Martins Torres 2019ª: 324 AGN, Matrimonios, vol. 189, exp. 19, f. 1-3 |
| | 1719 | Antonio Franco | | Glass furnace owner | | AGN, Matrimonios, vol. 189, exp. 19, f. 1-3 Martins Torres 2019ª: 324 |
| | 1719 | José Ladrón de Guevara | | Tendero de vidrios (glass merchant) | Spanish | Martins Torres 2019ª: 324 AGN, Matrimonios, vol. 165, exp.115 |
| | 1720 | Antonio Álvarez | | | | Fernández 1990: 259 |
| | 1721 | José Pavón | | Maestro vidriero (master glassmaker) | Appraised the window glass and mirrors in the home of Francisco Ximenez Paniagua. | González Franco et al 1994: 294. |
| | 1722 | Joaquín de Leyba | | Vidriero (glassmaker) | Spanish, 46 years old | AGN, Matrimonios, vol. 90, exp. 160, f. 406-410. |

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| | 1724 | Joaquín de Luna | | | | Martins Torres 2019a: 325 |
| | 1726 | Miguel de Olarce/Olarte | | Maestro vidriero (master glassmaker) | Calle de la Acequia | López Reyes 1985: 151 AGN Matrimonios, vol. 78, exp. 21, f.112v-113 |
| | 1726 | Salvador Maldonado | | Vidriero (glassmaker) | Spanish, 19 years old, resident in the street of Jesús Nazareno, worked with the master Miguel de Olarce | López Reyes 1985: 151 AGN Matrimonios, vol. 78, exp. 21, f.112v-113 |
| | 1726 | José Antonio Gómez de Villegas | | Owner of glass furnace | Mixcoac | Martins Torres 2019b: 129 (table 13) |
| | 1727 | Manuel Gomez | | Oficial de vidriero (officer glassmaker) | Free pardo, 29 years old, married, lives down from Puente del Ataud int he houses of the Colegio de San Pedro y San Pablo | Martins Torres 2019b: 130 (table 14) AGN Matrimonios, vol. 4, exp.1, f. 4-4v |
| | 1728 | Micalea Gerónima Becerra | | Owner of glass furnace | Located on the street that goes from the convent of Nuestra Señora de la Merced to the Colegio de San Pablo down the bridge that they call "del ataúd" (of the coffin) | AGN, Civil, vol.350, exp. 2, f. 132-263v |
| | 1728 | Don Miguel de Izeto | | Owner of a glass furnace and merchant | Sold his furnace to Micaela Gerónima Becerra | AGN, Civil, vol.350, exp. 2, f. 132-263v |
| | 1728 | Antonio Franco | | Maestro vidriero (master glassmaker) | Appraised the glass furnace sold to Micaela Gerónima Becerra | AGN, Civil, vol.350, exp. 2, f. 132-263v |
| | 1729 | Nicolás de Santa Ana | | Vidriero (glassmaker) | Spanish, 23 years old, neighbor of *Suchimilco* (Xochimilco) glassmaker but he no longer works, he lives in the houses of the widow Josepha de Albarado | AGN Matrimonios, vol. 174, exp.33, f. 3 |
| | 1729 | Francisco Xavier Gómez de Villegas | | Maestro vidriero (master glassmaker) | Spanish | Martins Torres 2019b: 129 (table 13) |
| | 1732 | Francisco Xavier Gómez | | Labrador de vidrio (glass carver) | Spanish, Tlalnepantla and San Miguel | Martins Torres 2019b: 130 (table 14) |
| | 1732 | Manuel de Santoyo | | Vidriero (glassmaker) | Spanish, 28 years old, married, resident in the street of the hospice, | López Reyes 1985: 21 AGN Matrimonios, vol. 53, exp. 36, f.245 |

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| | | | | | houses of the convent of San Joseph de Gracia | |
| | 1732 | José de Santoyo | | Vidriero (glassmaker) | Spanish, 22 years old, resident in the street of the hospice, houses of the convent of San Joseph de Gracia | López Reyes 1985: 21 AGN Matrimonios, vol. 53, exp. 36, f.245v-246 |
| | 1733 | Juan Francisco Xuarez | | Vidriero (glassmaker) | | AGN, Matrimonios, vol. 227, exp. 35, f.182-185 |
| | 1733 | José Antonio Morales | | Vidriero (glassmaker) | Mestizo, single, 20 years old, lives in the Puente Colorado, houses of Don Eligio | AGN Matrimonios, vol. 145, exp.43, f. 3v |
| | 1734 | Felipe de Godoy | | Maestro Vidriero (master glassmaker) | Requested payment of 200 pesos of common gold in *reales* to the Archicofradía del Rosario, founded for the convent of Santo Domingo, assigned to him as the dowry of his wife María Ana de Heredia, *en la suerte de las huérfanas* (for the orphans) of the archconfraternity | González Franco et al 1986: 118; 1994: 175. |
| | 1734 | Manuel Rivera | | Vidriero (glassmaker) | Free pardo, mestizo<br>Has a debt for the rent of a house and furnace in Puente Colorado | AGN, Tribunal Superior de Justicia, Procesos Civiles, caja 110, exp. 3879, f. 1-19 |
| | 1734 | Antonio Gómez de Villegas | | | | Martins Torres 2019a: 324 |
| | 1736 | Alberto Joseph Pegueros | | Maestro vidriero (master glassmaker) | Signed a receipt for 19 pesos, for fixing three glass Windows in the chapel of the Archicofradía de Nuestra Señora del Rosario in Santo Domingo, where the holly image of Our Lady was transferred | González Franco et al 1986: 73; 1994: 296. |
| | 1742 | Antonio Miguel Hurtado de Mendoza | | Vidriero (glassmaker) | Spanish, married, 28 years old, lives in the Puente de Monzon in the houses of Santillan, the gatekeeper of the Audiencia | AGN Matrimonios, vol. 163, exp.40, f. 2v |
| | 1744 | Francisco Xavier Gómez | | Vidriero (glassmaker) | Spanish, married, 36 years old, lives in the Puente de la leña in the houses of Don Nicolás de Castañeda | AGN Matrimonios, vol. 121, exp.25, f. 195v-196 |

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| | 1745 | Francisco Girón | | | | Martins Torres 2019a: 325 |
| | 1749 | Manuel José de Rivera | | Maestro de vidriero (master glassmaker) | Married, 54 years old, lives in the apartado | AGN Matrimonios, vol. 34, exp.33, f. 124-124v |
| | 1751 | Miguel de la Parra | | | | Fernández 1990: 260 |
| | 1751 | Pedro Gómez de Navarrete | | Vidriero (glassmaker) | Spanish, single, 25 years old, lives in the barrio de Santa Cruz in the houses of Don Nicolas de Castañeda | Martins Torres 2019b: 130 (table 14)<br>AGN Matrimonios, vol. 145, exp.58, f. 3-3v |
| | 1752 | Migue José de la Parra | | | | Fernández 1990: 260 |
| | 1752 | Francisco Antonio Anaya | | | | Fernández 1990: 260 |
| | 1752 | José Nicolás Rodríguez | | Administrador de horno de vidrio (Manager of glass furnace) | Spanish, widow, 32 years old, manager of the glass furnace of Puente Quebrado, where he lives, in the house of the master | AGN, Matrimonios, vol. 109, exp.98, f. 414v |
| | 1754 | Buenaventura de Alcázar | | Vidriero (glassmaker) | Spanish, married, 40 years old, resident in the barrio de San Lázaro, houses of Santa Clara | López Reyes 1985: 187<br>AGN Matrimonios, vol. 84, exp. 57, f.308v- 309 |
| | 1756 | Pascual Antonio Delgado | Ciudad de México | Vidriero (glassmaker) | Castizo, widow, 40 years old, lives in the Puente de Solano in the houses of Don Pedro Navarrete | AGN, Matrimonios, vol. 140, exp.23, f. 6-6v |
| | 1756 | José Gómez | | Maestro de vidriero (master glassmaker) | Spanish, married, 60 years old, lives in the Apartado, houses of Mr. Aldaca | Martins Torres 2019b: 130 (table 14)<br>AGN, Matrimonios, vol. 150, exp.46, f. 3 |
| | 1760 | Marcos Antonio Ladrón de Guevara | | Vidriero (glassmaker) | Spanish, married, 23 years old, lives in the barrio de San Hipólito, house of Dr. Lozano | AGN, Matrimonios, vol. 180, exp.65, f.2v-3 |
| | 1766 | Vicente Ladrón de Guevara | | Maestro Vidriero (master glassmaker) | Spanish, married, 54 years old, resident in Santa María | López Reyes 1985: 80<br>AGN, Matrimonios, vol. 66, exp. 25, f.130 |
| | 1766 | Marcia Luisa de Arana | | Owner of a glass furnace | | Martins Torres 2019a: 403<br>AGN, Civil, vol. 10, exp. 27. |

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| | 1776 | Joaquín Antonio del Valle | Xochimilco | Vidriero (glassmaker) | Castizo, single, 22 years old, lives in the barrio de San Pablo | AGN Matrimonios, vol. 1, exp.7, f. 36-36v |
| | 1771 | Ventura Gerardo Bermúdez | | Vidriero (glassmaker) | Audits of his income, the witnesses were Sebastian de Soria, silversmith, and Juan de Montes de Oca, painter, who said he was “very poor and only works as glassmaker, and they don’t know how much he makes” | González Franco et al 1986: 116; 1994: 122. |
| | 1771 | José Escobar y Llamas | | Vidriero (glassmaker) | Spanihs (criollo?), 48 years old | Martins Torres 2019b: 134 (table 15)<br>AGN, Matrimonios, Vol. 105, Exp. 20, f.274-281 |
| | 1771 | Manuel Gil Estrada | | | | Martins Torres 2019ª: 324 |
| | 1784 | José Mariano Rio Frío | | | | Martins Torres 2019ª: 325 |
| | 1786 | Domingo Montes de Oca | | | | Fernández 1990: 260 |
| | 1786 | José Antonio Azcarate | | Graduador de vidrios y anteojos (maker of ophthalmic glasses) | | Martins Torres 2019ª: 325<br>AGN, Inquisición, vol. 1266, exp. 3, fs. 164-214 |
| | 1787 | Matías Grismaldo | | | | Fernández 1990: 260 |
| | 1790 | José Formida (Josef Ermida?) | | Vidriero (glassmaker) | Spanish, 27 years old, married, son of widow Clara Gómez, Spanish of Mexico, lives in Callejón del Vinagre no. 15, accesoria 1 | Censo de Revillagigedo, “Cuartel” 19, f. 1v. (3) |
| | 1790 | José Martañon (or Martuñon) | Mexico | Vidriero (glassmaker) | Spanish, 29 years old, single, lives and has a glass workshop in Callejón del Vinagre, no. 16 belonging to the Curato de Santa Cruz | Censo de Revillagigedo, “Cuartel” 19, f. 2. (4) |
| | 1790 | Micaela | | Criada del vidriero (servant of the glassmaker) | Servant of José Martañon | Censo de Revillagigedo, “Cuartel” 19, f. 2. (4) |
| | 1790 | Anselmo Trinidad | Chalco | Vidriero (glassmaker) | Tributary Indian, 23 years old, married with children, lived in | Censo de Revillagigedo, “Cuartel” 19, f. 20. (40) |

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| | | | | | Callejón del Vinagre in a casa de vecindad, room 3 | |
| | 1790 | Joseph Antonio Maya | Mexico | Vidriero (glassmaker) | Spanish, 26 years old, married, with children, lives in Puente de Leguizamo in front of the Pulquería de Celaya | Censo de Revillagigedo, "Cuartel" 15, f. 71-72 |
| | 1790 | Jose Amaya | | Vidriero (glassmaker) | Spanish, 36 years old, married, lives in Puente de Leguizamo in front of the Pulquería de Celaya | Censo de Revillagigedo, "Cuartel" 15, f. 71-72 |
| | 1790 | Bernardo Aguilar | Mexico | Maestro Vidriero del Apartado (Master glassmaker of the Apartado) | Spanish, 30 years old, married and has a son, lives on the street Chiconautla, no. 55, vecindad, vivienda 17 | Censo de Revillagigedo, "Cuartel" 14, f. 348 (701) |
| | 1790 | Mauricio Ruano | | Vidriero (glassmaker) | 33 years old, married, lives in Calle de las Moscas from north to south, on the sidewalk that faces west, Casa de Vecindad no. 5, Room 4 | Censo de Revillagigedo, "Cuartel" 26, f. 45 |
| | 1790 | José María Villaurrutia | Mexico | Vidriero (glassmaker) | 20 years old, married, has a child, lives in Calle de los Siete Príncipes east to west, north sidewalk, Room 3 | Censo de Revillagigedo, "Cuartel" 26, f. 64 |
| | 1790 | José María Aguilar | Mexico | Vidriero (glassmaker) | Spanish, 22 years old, married, with children. Lived in Calle de los Siete Príncipes, east to west, north sidewalk, Accesoria 22 | Censo de Revillagigedo, "Cuartel" 26, f. 63 |
| | 1790 | Don José Joaquín Montes de Oca | | Vidriero (glassmaker) | Spanish, 18 years old. Lived in Calle de Cueritos west to east, part of the Feligresía de San Sebastián, Casa de Vecindad 18, Room 3 | Censo de Revillagigedo, "Cuartel" 26, f. 193 |
| | 1790 | Manuel Escobar y Llamas | Mexico | Vidriero (glassmaker) | Indian, 40 years old, married, had children, lived in Callejón del Olivo, House 29, Room 15 | Censo de Revillagigedo, "Cuartel" 32, f. 46-47 (75-76) |
| | 1791 | Matías Grimaldo | | | | Martins Torres 2019a: 325 |
| | 1791 | José Antonio Ascárate | | Graduador de vidrios (maker of ophthalmic glasses) | Spanish, married, 45 years old, resident in the Plazuela de Vizcaínas no. 10 | López Reyes 1985: 179 AGN Matrimonios, vol. 82, exp. 99, f.434v-435 |

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| | 1791 | Juan Manuel de San Vicente | | Tienda de Cristales (glass store) | Neighbor of Mexico City, he has a glass store in the street of Plateros | AGN, Inquisición, vol. 1350, exp. 5, f. 1-8 |
| | 1791 | José Martiñón | | Owner of glass furnace | The furnace was located down from the Puente de Solano, in the street that goes to Santa Cruz | Martins Torres 2019a: 568<br>Gazeta de México 1791 |
| | 1792 | José Robles | | Mercader de vidrios (glass merchant) | Lives in the corner of la Monterilla | AGN, Inquisición, vol. 1368, exp. 18, fs.1-6 |
| | 1793 | Miguel Valladares | | Glass furnace owner | He has a glass furnace in the Calle del Horno with four officials. He appears in a list of artisans living in the *Cuartel* no. 17 in the Census of Revillagigedo. He is also mentioned in the *Cuartel* 19, with a glass furnace in the street of Santa Cruz | González Franco et al 1994: 344. |
| | 1793 | Pablo Fernández | | Caxon de christtal (glass store) | | Fernández 1990: 260 |
| | 1793 | Juan de Sanvicente | | Caxon | | Fernández 1990: 260 |
| | 1794 | Pablo Antonio Aguilar | | Oficial vidriero (officer glassmaker) | Request that he is excluded from the provisional military regiment so that he can return to the house of coinage to work in the glass furnace | AGN, Casa de Moneda, vol.81, exp.3, f. 133-148 |
| | 1795 | José Joaquín Serrano | | Azogador de vidrios (application of quicksilver on glass) | Spanish, married, 50 years old, lives in the Puente Quebrado in the Baño de los Dolores | AGN Matrimonios, vol. 158, exp.26, f. 3-3v |
| | 1795 | Pablo Antonio Aguilar | | Vidriero del Apartado General (glassmaker of the Apartado General) | Soldier of the military requesting permission to return to glassmaking | AGN, Casa de Moneda, vol.457, exp. 21, f. 240 |
| | 1799 | Bernardo Aguilar | | Maestro vidriero del Real Apartado (Master glassmaker of the Real Apartado) | Requests support for no longer being able to work due to accidents | AGN, Casa de Moneda, vol. 451, exp. 9, F. 164-173;<br>AGN, Casa de Moneda, vol. 50, exp.14, f. 194 |

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| | 1799 | Juan Gutiérrez del Corral | | Tienda de cristal y loza (Store of glass and ceramics) | Deceased | AGN, Indiferente Virreinal, caja 5234, exp.29, f |
| 19th century | 1800 | Cosme Damian Hernández | | Vidriero (glassmaker) | Indian, single, works in the furnace of Santa Cruz | AGN, Padrones, vol.103, f.144 |
| | 1800 | Juan Patricio Salazar | | Vidriero (glassmaker) | Indian, married without children, Calle de la Santísima | AGN, Padrones, vol.103, f.144 |
| | 1800 | José María de la Rosa | | Vidriero (glassmaker) | Indian, he says he is Spanish, single, Puente Colorado | AGN, Padrones, vol.103, f.144 |
| | 1800 | Lorenzo Baños | | Vidriero (glassmaker) | Indian, married and has one daughter, works in the glass hurnace of Santa Cruz | AGN, Padrones, vol.103, f.144v |
| | 1800 | Paulino Antonio Amaya | | Vidriero (glassmaker) | Indian, married and has one daughter, Callejón del Vinagre | AGN, Padrones, vol.103, f.144v |
| | 1800 | Pedro Ybarra | | Vidriero (glassmaker) | Indian, widow, no children, Works in the glass furnace of Santa Cruz | AGN, Padrones, vol.103, f.144v |
| | 1802 | Bernardo Aguilar | | Operario vidriero del Apartado (glassmaker at the Apartado) | | AGN, Casa de Moneda, vol. 483, exp. 358, f. 1-3v |
| | 1804 | Lorenzo Laureano Millan | | Vidriero de la Casa de Moneda (glassmaker of the House of Coinage) | Requests help because of a disease | AGN, Casa de Moneda, vol. 50, exp.18, f. 289-301 |
| | 1805 | Bentura Godoy | | Oficial vidriero (officer glassmaker) | Obtained a soldier position | AGN, Casa de Moneda, vol.148, exp.14 |
| | 1806 | Juan de Dios de la Cueva | | | | |
| | 1806 | José Mariano Río Frío | | | | |
| | 1809 | Bentura Godoy | | Oficial vidriero del Apartado (Officer glassmaker at the Apartado) | | AGN, Casa de Moneda, vol. 148, exp. 28 AGN, Indiferente Virreinal, caja 2946, exp. 18 |
| | 1816 | José María Piza | | Maestro vidriero del apartado de la Casa de Moneda | Taught the craft to three apprentices. Worked in Casa del Apartado since it was incorporated | AGN, Casa de Moneda, vol. 31, exp. 16, f. 183-191v |

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| | | | | (Master glassmaker at the House of Coinage) | to the Crown. In 1816, he said he had retired about 8 years before for health reasons. | |
| | 1816 | Mariano García/Salazar | | Vidriero, Casa del Apartado (glassmaker, Casa del Apartado) | Was the apprentice of José María Piza | AGN, Casa de Moneda, vol. 31, exp. 16, f. 183-191v |
| | 1816 | Luis Godoy | | Operario del horno de vidrio de la Casa Real del Apartado (Worker in the furnace of the Casa del Apartado) | Spanish, 39 years old, was the apprentice of José María Piza | AGN, Casa de Moneda, vol. 31, exp. 16, f. 183-191v |
| | 1816 | Ventura Godoy | | Vidriero, Casa del Apartado y soldado (glassmaker at the Casa del Apartado and soldier) | Spanish, 32 years old, was the apprentice of José María Piza | AGN, Casa de Moneda, vol. 31, exp. 16, f. 183-191v |
| | 1816 | Miguel Gerónimo García | | Oficial de Vidriero, Casa del Apartado (officer glassmaker at the Casa del Apartado) | Indian, 50 years old, was the apprentice of Aguilar and later of José María Piza | AGN, Casa de Moneda, vol. 31, exp. 16, f. 183-191v |
| | 1840 | Miguel Caballero | | Vidriero (glassmaker) | Presented receipts for the reposition of the glass in the convent of Jesús María | González Franco et al 1986: 116; 1994: 125. |
| | 1842 | | | | 10 glassmakers registered in the *Guía de forasteros político-comercial de la Ciudad de México para 1842* | Fernández 1990: 262-263 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 1843 | José María Valdés | | Pequeña casa de cristalería (small crystal store) | | Fernández 1990:263 |
| | 1850 | Francisco Ayala | | Vidriero (glassmaker) | Worked in the repair of several properties of the convent of La Encarnación. | González Franco et al 1986: 18; 1994: 116. |
| | 1854 | | | | 7 glassmakers registered in the *Guía de forasteros de la Ciudad de México para 1854* | Fernández 1990: 263 |
| | 1864 | | | | 7 glassmakers registered in the *Guía de forasteros de la Ciudad de México para 1864* | Fernández 1990: 263-264 |
| | 1888-1890 | | | | 22 glassmakers refistered in the *Directorio Estadístico de la República Mexicana* | Fernández 1990: 264 |
| | 1888 | Rafael M. Enciso | Apam (Apan, Hidalgo) | Conocimientos en fabricar vidrios planos, capelas, botellas y otros (knowledge to make flat glass, glass covers and bottles) | 21 years old, got associated with Ignacio Beléndez to industrialize pulque production | Reyna and Krammer 2012: 42 |
| | 1889 | Camilo Avalos Razo | | Maestro acabador (Finishing master/master glassmaker) | Glass workshop at Carretones. His sons Odilón, Luis, Francisco, and Enrique were also glassmakers. Odilón later established a glass workshop in Guadalajara, Jalisco. | Martínez Peñaloza 1982 Fernández 1990: 265 |
| 20th century | 1901 | Victor Francisco Marcos y Urrutia | | Pintor de vitrales (painter of stained glass) | Spanish | Fernández 1990: 265 |
| | 1907 | Felipe Derflingher | | | | Fernández 1990: 265 |

APPENDIX 4. PEOPLE INVOLVED IN THE GLASS INDUSTRY IN PUEBLA

| Century | Year(s) | Name | Place of Origin | Occupation | Notes | Reference |
|---|---|---|---|---|---|---|
| 16th century | 1542 | Rodrigo Espinosa | Villa de Guadahortuna, Granada, Spain | Vidriero (glassmaker) | From Villa de Guadahortuña, legitimate son of Cosme Despinosa, from Despinosa de los Monteros, and of Francisca Mellada, and he has been for nine years in New Spain, and he is married, and has two children, and is waiting for his wife, and he is por, sick, and in need | Icaza 1923: 191; Fernández de Echeverría y Veitia 1962 [1780]:304 Fernández 1990: 44 |
| 17th century | 1612-13 | Diego López del Huerto | | Vidriero (glassmaker) | Street of Sant Josephe that goes from the plaza, he payed 5 pesos of *alcabala* tax, and 4 pesos the following year | AHMP, Alcabalas, Vol. 3, 1627-35, f. 18, 34 |
| | 1618-20 | Diego López | | Vidriero (glassmaker) | Street of Sant Joseph, he payed 2 pesos of *alcabala* tax. In 1619 he was in the Street that goes from El Carmen to Los Descalzos. In 1620, he was in the street of the botica de Teran towards Los Descalzos | AHMP, Alcabalas, Vol. 3, 1627-35, f. 18, 138v, 160v |
| | 1622-23 | Pedro Sánchez | | Vidriero (glassmaker) | Following half the Street to Los Descalzos. He payed 4 pesos of *alcabala* tax. In 1623, he was in the Calle del Carmen towards the *Yglessia Mayor* (main church) | AHMP, Alcabalas, Vol. 3, 1627-35, f. 229, 253 |
| | 1627-33 | Geronimo Gomes | | Bedriero (glassmaker) | Calle del Carmen towards the Iglesia Mayor, following the Street to Los Descalsos. He payed 6 pesos of *alcabala* tax. In 1632 he payed 16 pesos, and the following year 10 pesos | AHMP, Alcabalas, Vol. 2, 1612-1627, f. 18, 39v, 62, 97v, 115v,130v |
| | 1629-31 | Pedro Sanchez del Guerto | | Bidriero (glassmaker) | Calle de San Miguel towards the mil of Formicedo. He payed 4 pesos of *alcabala* tax | AHMP, Alcabalas, Vol. 2, 1612-1627, f. 58v, 93v, 112 |
| | 1630 | Antonio Cortes | | Hace quentas de vidrio | Calle del Señor San Joseph. He payed 2 pesos of *alcabala* tax | AHMP, Alcabalas, Vol. 2, 1612-1627, f. 95 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 1632-33 | Juan Navarro | | Vidriero (glassmaker) | Calle de la Audiencia. He payed 25 pesos of *alcabala* tax. The following year he payed 10 pesos | AHMP, Alcabalas, Vol.2, 1612-1627, f. 120v, 150v |
| | 1642 | Diego Becerra | | Bedriero del candil (lampworker) | | Toussaint 1974:146 |
| | 1660 | Juan Gómez de Villegas | | Maestro mayor de la fábrica de hacer vidrio y loza fina (Major master of glassmaking and fine ceramics) | Spanish, has aglass furnace in the Calle del Venado (Street of the Deer) | AGN, General de Parte, vol. 11, Exp. 42, f. 48-52 |
| | 1679 | Antonio Díaz | | Maestro vidriero (Master glassmaker) | Bids to make glass grenades demanded by the viceroy | AHMP, Tomo 152, Legajo 1517, f.99 |
| | 1679 | Alonso Pardo | | Maestro vidriero (Master glassmaker) | Bids to make glass grenades demanded by the viceroy. He wins the comisión. | AHMP, Tomo 152, Legajo 1517, f.100 |
| | 1684 | Alonso Pardo | | Maestro vidriero (Master glassmaker) | Bids to make glass grenades demanded by the viceroy | AHMP, Tomo 153, Legajo 1531, f.99v |
| | 1684 | Alonso Gómez | | Maestro vidriero (Master glassmaker) | Bids to make glass grenades demanded by the viceroy. He wins the comisión. | AHMP, Tomo 153, Legajo 1531, f.99v |
| | 1686 | Juan de Portes | | Vidriero (glassmaker) | At least two of his sons were glassmakers. | Morales 2016: 1691. Martins Torres 2019b: 133 (tabla 15) |
| | 1686 | Alonso de Portes | | Vidriero (glassmaker) | Son of Juan de Portes. He had a brother who was also a glassmaker but his name is unknown. | Morales 2016: 1691. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Martins Torres 2019b: 133 (tabla 15) |
| | 1687 | Juan del Río Gómez | | Vidriero y carpintero (glassmaker and carpenter) | Intervened in the work on Capilla del Rosario in the convent of Santo Domingo, ordering four glass panels (*vidrieras*) for the tabernacle. | Castro Morales 1963: 319. Pizarro Gómez 1997: 73. Martins Torres 2019b: 130 (tabla 14) |
| | 1695 | Juan de Armijo Villalobos | | Vidriero (glassmaker) | He was part of the contract for one of the altarpieces (Congregación de Nuestra Señora de los Dolores) in the oratory of San Felipe Neri, in the Templo de la Concordia | Castro Morales 1963:422 Martins Torres 2019b: 133 (tabla 15) |
| 18th century | 1712 | Juan Gómez de Villegas? | | | His glass furnace was in Calle del Venado | Leicht, 1934: 459 |
| | 1719 | Francisco Xavier de la Fuente | | Asistente en horno de vidrio (helper in glass furnace) | Spanish, single, 20 years old, lives in the barrio de San Lázaro, helps in the glass furnace of Antonio Franco | AGN Matrimonios, Vol. 189, exp.19, f. 2 |
| | 1719 | Antonio Franco | | Owner of glass furnace | | AGN Matrimonios, Vol. 189, exp.19, f. 2 |
| | 1720 | Luis Pardo | | | | Fernández 1990: 259 |
| | 1721 | Miguel Maldonado | | Maestro de vidriero y dorado (Master of glassmaking and gilding) | In 1723 he received 42 pesos from one of the stewards of the Limpia Concepción for the manufacture of the stained glass windows of Nuestra Señora, and three pesos for fixing another one on the window of the chapel | Toussaint 1974: 146 González Franco et al 1994: 249. |
| | 1722 | Antonio de Quiñones | | Perito en espejos y cristal (appraiser of mirrors and crystal) | | Toussaint 1974: 146 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 1728 (1720, 1723?) | Antonio Pardo | | | Established a furnace in 1723 in front of the fence of the convent of Santa Teresa (Av. 10 Oriente 1), later Calle del Horno del Vidrio | Toussaint 1974: 146<br>Cordero y Torres 1965: 221<br>Leicht 1934:188 |
| | 1744 | Alonso Pardo | | | | Toussaint 1974: 146<br>Leicht 1934: 189 |
| | 1770-1800 | José Mariano Pardo | | | Spanish born in 1740, he had six Maiden daughters in 1773 | Toussaint 1974: 146<br>Leicht 1934: 189 |
| | 1772 | Lorenzo Pardo | | Vidriero (glassmaker) | Associated with Manuel de Lara to establish a glass furnace | AGN, General de Parte, vol. 50, exp.166, f. 155-155v |
| | 1772 | Manuel de Lara | | | Associated with Lorenzo Pardo to establish a glass furnace | AGN, General de Parte, vol. 50, exp.166, fs. 155-155v |
| | 1786-1814 | Juan Pardo | | | Glass furnace on the south sidewalk of the street on the side of the church of Santo Domingo (Calle Mariano Arista). In 1814 the glass furnace is no longer there | Leicht 1934: 21<br>Cordero y Torres 1965: 221<br>Fernández 1990:261 |
| 19th century | 1802 | | | | Humboldt observed two glass factories | Humboldt1966 [1822]: 454 |
| | 1806 | Miguel Ignacio Rementería | | | Glass workshop in Calle de Iglesias | Toussaint 1974: 146<br>Fernández 1990:260 |
| | 1807 | Ildefonso Silva | | Dueño de horno de vidrio (owner of a glass furnace) | Mentioned in an appraisal of his possessions after his death | AGN, Tribunal Superior de Justicia de la Ciudad de México, Documentos Notariales, caja 310, exp.50, f |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 1809 | Luis | | Fabrica vidrios (manufactures glass) | French, white, 45 years old approximately, married in New Orleans and lives in several places | AGN, Inquisición, vol. 1445, exp. 7, f. 23-24 |
| | 1821 | Mariano Santiago Álvarez | | Manufacturero de vidrio y loza (manufacturer of glass and ceramic) | Also Lieutentant, elected alderman and chosen to represent the master potters on the Junta de Artesanos (Artisans board) | Thompson 1989: 89 |
| | 1822 | Vicente Laso | | Aprendiz de vidriero (apprentice glassmaker) | | Fernández 1990:262 |
| | 1822 | | | | 35 glassmakers registered in an 1822 census at Archivo del Ayuntamiento de Puebla | Fernández 1990: 261-262 |
| | 1838 | | | | Furnace in the Portería de Santa Catarina | Cordero y Torres 1965: 221 |
| | 1838-1885 | | | | Compañía Empresaria, in the street Solar de Castro (Av. 8 Poniente 500). Esteban de Antuñano was one of the founder associates. French and Belgian glassmakers worked there. | Cordero y Torres 1965: 221 |
| | 1838-1847 | | | | La Casa de Vidriería | Cordero y Torres 1965: 221; Leicht 1934: 189 |
| | 1846 | | | | Fábrica de Vidrios Criollos (Factory of creole glasses) in the Plazuela de San Agustín | Cordero y Torres 1965: 221 |
| | 1852 | | | | Four glass furnaces in Portería de Santa Catarina, two in Calle de Iglesias, and one in Capilla de los Dolores | Cordero y Torres 1965: 221 |
| | 1852 | | | | Factory of flat glass in the barrio de San Antonio | Cordero y Torres 1965: 221 |
| | 1857 | Quinard (Kunhardt) brothers | | Master glassmakers | Brothers Carlos, Juan and Felipe Quinard (Kunhardt) established a glass workshop | Fernández 1990: 263 |
| | 1885 | | | | Four glass furnaces: Solar de Castro (Av. 8 P. 500) (until 1930); Capilla de Dolores; Mesón de Sosa; and Fuente de Belem | Cordero y Torres 1965: 221 |
| | 1896 | | | | Three glass furnaces: Meson de Sosa; Fuente de Belem; and Obraje de Lomba | Cordero y Torres 1965: 221 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 20th century | 1947 | | | | Glass furnace in callejón de I. Llave<br>Furnace Corazón de Jesus (closed in 1947) | Cordero y Torres 1965: 221-222 |
| | 1963 | | | | No active glass workshops or factories, glass is coming to Puebla from Monterrey, NL | Cordero y Torres 1965: 221-222 |

APPENDIX 5. TRANSCRIPTION OF TESTIMONIES BY FRANCISCO SOLARTE AND HERNANDO RAMÍREZ[298]

24 F[ebrer]o 1628
Desele liz[enci]a

Manuel Sanchez negro criollo de San Juan de [U]Lua estante en esta ciudad de seys años a esta parte esclabo de Fran[cis]co Solarte enconmendero besino de esta ciudad cargo quepo soy soltero y libre de matrimonio y me quiero casar con Fran[cis]ca negra tierra angola esclaba de doña Beatris de Fodoñosa biuda besina desta al barrio de Sancto Domingo y para que tenga efecto el dicho matrimonio
A v[uestra] m[erce]d pido y suplico mande se nos resiba ynformasion desolteros y libres de mantrimonio y se nos de licencia para que los curas de la catredal [sic] de esta ciudad nos amonsesten y casen pido justicia v[uestr]a
…
[at the margin]: T[estig]o por el
Me[xi]co a v[ein]te y quatro de febr[er]o de mil y seis[cient]os y v[ein]te y ocho a[ño]s para la dicha ynformacion se recibió juramento por dios y la cruz en forma según d[erech]o de un negro que se dijo llamar Hernando Ramirez y ser criollo de la Beracruz y que vecino desta dha ciu[da]d junto al Carmen y que es oficial de bidriero y trabaxa en casa de Juº [Juan] de Mora al barrio del Carmen y aviendo jurado prom[etid]o de decir v[erda]d y siendo preguntado = dixo que conoce a Manuel Sanchez negro cont[eni]do en el pedim[en]to desde que el susod[ic]ho hera muchacho de hedad de dies a[ño]s y le conocio en la ciu[da]d de la Nueba Veracruz much t[iem]po donde le comunicó hasta que abra seis a[ño]s que bino a esta ciu[da]d y en ella le a comunicado asi mismo en casa y serbi[ci]o de Fran[cis]co de Solarte encomendero y vecino della y sabe por la dha comunicación que es soltero y libre de mantrim[oni]o y que como tal se pue[de] casar librem[en]te esto dixo ser la v[erda]d so cargo del juran[en]to f[ec]ho y no firmo que dijo no sabia declaro ser de hedad de cinquenta y quatro a[ño]s poco mas o m[eno]s =
Ante my Fran[cis]co Berneo [rubric]
Es[criban]o app[ubli]co

[at the margin]: T[estig]o por ambos
E luego para la d[ic]ha ynfor[macio]n se r[eci]vio juram[en]to por dios y la cruz en forma según d[erech]o de una negra que se dijo llamar Agustina de la Concepcion y ser criolla y esclaba de Don Baltasar Guerrero vecino desta ciu[da]d junto a la casa de la moneda y abiendo jurado prometio de decir v[erdad]d y siendo preg[unta]da dijo que de seis a[ño]s a esta p[art]e conoce a Manuel Sanchez negro cont[eni]do en el pedim[en]to y ordinariam[en]te le a tratado y comunicado en esta ciu[da]d por soltero y libre de matrim[oni]o como tal del d[ic]ho t[iem]po sabe se puede casar con francisca negra contenida en la petición a quien asi mismo conoce de diez a[ño]s a esta p[ar]te y siempre la a comunicado por soltera y libre para poderse casar esto dijo ser la verdad so cargo de juram[en]to f[ec]ho y no firmo que dixo no savia no supo decir su hedad parecio en su aspecto de mas de cinquenta a[ño]s =
Ante my Fran[cis]co Berneo [rubric]
Es[criban]o app[ubli]co

[298] AGN, Matrimonios, vol. 48, exp. 94, f.251-252.

TRANSLATION

February 24, 1628
Give him license

Manuel Sanchez black criollo of San Juan de Ulua being in this city for six years on this part, slave of Francisco Solarte, encomendero, neighbor of this city charge [?] that I am single free of marriage and I want to marry Francisca, black [from the] land of Angola, slave of Doña Beatris de Fodoñosa, widow, neighbor of this [city], in the *barrio* of Santo Domingo and so that the marriage can take place
To your mercy I ask and beg that you order that information is received of our singleness and freedom to marry and a license is given to us so that the priests in the cathedral admonish and marry us, I ask [for]your justice …

[at the margin]: Witness for him
Mexico, February 24, 1628 for the mentioned information, oath was received for God and the cross according to law from a black [man] who said his name was Hernando Ramírez and to be *criollo* from Veracruz and that [is a] neighbor of the said city [Mexico] besides the Carmen and he is officer glassmaker and works in the house of Juan de Mora in the barrio del Carmen and having sworn and promised to tell the truth and being asked = he said he knows Manuel Sánches, black, contained in the plea, since he was a young boy aged ten years old and he met him in the city of Nueva Veracruz for a long time where he communicated to him that it has been six years that he came to this city [Mexico] and there he has also communicated in the house and service of Francisco Solarte, *encomendero* and neighbor of it [Mexico City] and knows because of said communication that he is single and free to marry and as such, he can get married freely, this he said to be true under oath and did not sign because he does not know how, he declared being 54 years old more or less=
Before me Francisco Berneo [rubric]
Public notary

[at the margin]: Witness for both
And then, for said information oath was received for God. And the cross according to law from a black [woman] who said her name was Agustina de la Concepcion and to be *criolla* and slave of Don Baltasar Guerrero, neighbor of this city [Mexico City] besides the Casa de la Moneda (mint) and having sworn and promised to tell the truth and being asked she said that since six years ago in this part she knows Manuel Sanchez, black, contained in this plea, and has ordinarily interacted and communicated with him in this city, he is single and free of marriage as such for that time, she knows he can marry Francisca, black contained in this plea, whom she also knows for ten years this part and she has always communicated to be single and free to get married, this she said to be the truth under oath and did not signed because she does not know how, she said she did not know her age, she appears to be over fifty years old =
Before me Francisco Berneo [rubric]
Public notary

# APPENDIX 6. NINETEENTH-CENTURY GLASS RECIPES

Guadalajara, April 15, 1820

First formula of transparent crystal

Flint..……………………………………...… 200 pounds
Potassium nitrate …………………………… 090 idem
Red litharge minium [red lead?]……………. 070 idem
Manganese………………………………..… 7 ounces
Borate soda…………………………………. 00[2 pounds crossed-out] I mean, 4 ounces
Potash………………………………………..16 pounds

Method to mix these ingredients

In a trough, one puts firstly the ninety pounds of potassium nitrate.
On top of the nitrate, one puts the seventy pounds of red litharge minium.
On top of the minium, one puts the two hundred pounds of flint.
With a few of the powders of the flint, one mixes the seven ounces of manganese, to extend and spread it over the flint.
Then one stirs twice, from top to bottom, all this mixture.
Out of this mixture, one takes a few powders to mix them with the sixteen pounds of potash, in order to prevent that it gets humid and to avoid the formation of lumps. And after the potash is incorporated with those powders, this is sieved through a sifter on top of the whole composition.
Once this has been done, everything is mixed well, until all the mixture acquires a uniform color, and then it is taken to the frit furnace, which should be glowing, so that the frit will be kept in that degree of heat, spread out through the floor for four hours, or more if it is necessary to perfect the frit.
One can known that the frit is well done when all of it turns to a uniform and opaque white color, and when the particles of flint lose the shape of their borders and corners, and become flattened. And to achieve this degree of perfection equally on all the frit, it is recommended to stir it every half of a quarter of an hour in the furnace, and make sure that when it is extended on the floor of the furnace, it is not placed on thick layers or prominent and uneven mounds.
Once the frit is finished, it is transferred to the crucibles to melt it, like it has been said, but if when the frit was made lumps were formed in it, as a contingency measure, it is important to sieve it to separate the lumps so these can be grinded, and one should only put in the crucibles whatever came out as a powder after sieving.
This way of making frit should be understood as the method for the compositions that will be done later, but not for the one made today, because this one, once it has been well mixed, it is sieved and put into the crucibles to melt in the following way.
Certainly, since the furnace is new and cold, the crucibles can be introduced and arranged while cold, and then light the fire up, until the furnace and the crucibles are incandescent.
Once they are in this condition, one begins to put the mixture into the crucibles, which are not filled up at once, but in three stages. In the first one, the crucible is filled up with a little more than a third of its capacity; In the second one, another third more or less; and in the third one, whatever is left.

After the first part has been placed in the crucibles, the furnace is lighten up to the maximum, that is, until the flame protrudes out of the furnace doors and windows one foot [palmo], that is, about four fingers and no more, because that would be wasting fire uselessly.
Conducting the fire in this way strongly, if when twelve hours after the melting was begun are approaching, the first part will be done.
One can know that said first part it is well molten when the small air bubbles contained in the samples taken out, are not thicker than half a line more or less.
When the first part is well molten, the second one is placed in the mortars; when that one is well molten too, the third one is added; and when all of them are fully molten, which regularly occurs after 26 hours, then the fire [heat] is lowered but without letting the furnace cool down, it should be kept heated-up but with a lesser degree of fire so that in this way the material that is molten in the crucibles can repose for ten hours.
As the material reposes during these ten hours, the air bubbles that it contained come up to the surface bringing up impurities and extraneous matter that were in the mix. This is why it is better to wait for the mortars for ten hours, and after they have foamed, the material can be taken out by the spoonful and thrown into cold water, where it forms small chunks with a borsa [?], but making sure to renew the cold and clean water as much as possible because this way the procedure yields more perfect results.
Once this "casco" is cold and broken into small pieces that are not bigger than a hazelnut, they are well dried and mixed into the following composition:
Flint ……………………….…….. 200 pounds
Potassium [potash] nitrate ……. 100 idem
Litharge minium………………. 072 id
Potash…………………………. 012 id
Borax………………………….. 000 id one ounce
Manganese……………………. 000=[70 crossed out] ounces seven ounces
"Casco" all that was made from the precedent formula ……000=0=0
Then this is mixed together as well as possible and it is placed in the crucibles to melt in the same way mentioned before, in three parts. The fire is activated until it can yield a perfect and fine melt. Once it is fine, the fire is mitigated but the furnace is kept very hot for four hours. After this time the surface foams and it can be worked, but this can happen after 8 hours of this second melt.
I forgot to say before that the first part that is put into the crucibles, once it has molten, it should be checked if the color is greenish, and if that is the case, manganese should be added in quantity of a fourth of what had been added before, so that if it had eight ounces, then two ounces should be added, and so on and so forth, and if even this is not enough, another fourth part of manganese should be added to the third part.

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In the morning at 11 thirty the crucibles were filled up for the first time with the first composition, at eleven pm of that same day, the crucibles were filled up for a second time with the same composition, and today 19 at 12 the crucibles were still hard. For this reason, 20 pounds of nitrate and 30 of litharge minium were added with one ounce and two "adarmes" [about 1.79grams] of manganese. Of this were added before to the first 7 ounces, 6 second ones.

April 27 of 1820
Frit No. 1
Method to make frit in a suitable quantity for a certain time

Measure the potassium nitrate, six “arrobas” [11.5 kg] twenty pounds, that make fifty pounds – 170 [110?] pounds
Of flint, eight “arrobas” that make 200 pounds
Both are well mixed and then ten pounds of potash are weighted and these are well mixed with the nitrate and the flint: these are then ten pounds of potash and of manganese one ounce.
The total weight of this mixture is fifteen “arrobas” and fifteen pounds, or what is the same, three hundred ninety pounds.
This mixture is made or repeated successively for six times, one after the other, and in this way one gathers ninety three “arrobas” fifteen pounds, that make up the six compositions and with this one has suitable frit for a certain time.
In order to have good frit that can be used with confidence, this has to be done very carefully. To do this, the frit furnace is loaded with a portion of the aforementioned mixture, which is extended on the floor of the furnace in as much quantity necessary to cover the whole extension of the furnace floor, making sure all of the surface is occupied by a layer of mixture that is three fingers thick or edgewise.
Once the mixture is extended on the floor of the frit furnace as it has been said, the grill is fired up by degrees, so that it goes up little by little. For this, the fire is primed with one or two logs, and once these stop producing a lot of smoke, more logs are added, when there is no more smoke, more logs are added, and so on and so forth until the furnace is red hot or glowing. And when the furnace reaches this stage and the flame protrudes a little from the mouth, then we stop trying to increase the fire, and instead we feed the furnace every once in a while with a log to keep that degree of heat, which is enough to make good frit.
When it is being made, and the furnace is kept at an adequate heat, it is important to only move the mixture or composition that is on the floor of the furnace when it is necessary. To do this, one has to watch the mixture attentively to see if all the humidity that it usually has in it has dried out well, and we know this because it stops emitting vapors and it doesn’t look dun, or white in some parts and dun in others. But the most clear sign is when all the surface of the mix that is extended on the furnace becomes a uniform white color. Once this state is reached the mixture is moved for the first time, bringing what was underneath to the top, and the top layer to the bottom using a shovel and a rake, and it is not moved again until all the surface of the mixture becomes uniformly white. This method will be followed later to stir the mixture many times until the frit reaches perfection equally all over.
It will be known that the frit has been perfected when all of it is fluffed and has an opaque white color, and when we take the powder between the fingers, we can tell that the Flint grains have become rounded and lost the points and corners that they had before performing this operation.
If this is done correctly, controlling the fire by means of the aforementioned method , letting it dry before stirring it, and avoiding to move the lower part until the upper part is well burnt, it will be seen that no lumps or clots will be left, but if unfortunately the fire is uneven, if by contingency the fire goes up more than necessary, and if while the mixture is humid it is stirred, then this results in a frit of diverse colors that are then transferred to the glass, and it also results in lumps that need to be separated to grind them and use them for ordinary glass.

But if the frit is well made all over, then it is saved in boxes to use it in the compositions that need it to be melt in the mortars and make “casco”  using the method in sheet number two.

Note
Before beginning to use the frit that has to result in fifteen “arrobas” fifteen pounds, or three hundred ninety pounds of composition, the frit is weighed and the weight is registered, so that this serves as measure and so we can know how many “arrobas” of frit we have to make the compositions.

April 27 of 1820
Nº 2º

First compositions to make “casco”
Method to make the composition with the frit to make “casco”
Six “arrobas” [11.5 kg] of frit are weighed which are two hundred and fifty pounds
……………………………………………………… 250 pounds
Of potassium nitrate, four pounds ….. 004 pounds
Of manganese, half an ounce ……..……. 000 ½
All of these powders are well grounded and well mixed until we achieve a mass of uniform color, this is placed in the crucibles or mortars, which should be sizzling hot in the furnace.
The way to load the mortars is doing it in three stages. In the first one, one puts a little more than one third of the quantity, in the second one another third, and in the third one whatever is left to fill them up, making sure that this is done without causing them to spill or overflow.
During this operation, it is important to observe the following order. Once the first load is in the mortars and the furnace is at a good heat, the fire must be kept alive and uniform so that the material or glass mass melts well. We will know that it is well melted when the testers that are withdrawn have no bubbles or “eyes” that surpass the size of one line, instead those will be half a line more or less.
Once the first part is well melted, the second part is added to the crucible, and once this is ready, the third one is added. And when the last one is well melted, like the others, then everything is taken out and poured into cold water,  which should be renewed constantly so that it does not get hot, and so the glass breaks and crumbles effortlessly like if has to be done.
For this operation, two water basins are filled up and, in one of these the glass is poured, and in the other the metal tools and spoons are frequently quenched, because if every time that they are taken out of the furnace the tools are not cooled down, not only do they stick to the glass, but they also rust and then they soil the glass with flakes; but if we cool them down in water every time that they are taken out of the furnace nothing of that sort happens and we are able to achieve a clean “casco.”
In order to keep the water in the basins always fresh, these are placed at the extreme of one of the beams of the aqueduct, and in said extreme we put two tin barrels, one thicker so that the water falls into the glass basin, and one narrower so that the water falls into the basin where the tools will be quenched.
Having achieved by this means a good “casco,” it is well dried and stored to be used for the compositions that will be reduced into another one on the working furnace.

Note
During the melting of the "casco," it is better not to remove the salt that floats on the crucibles because this would slow down the melting.
Only when the salt is so abundant that we fear it will melt the crucibles, or when it is jumping from the crucibles to the vault/dome and walls of the furnace, only then will it be taken out by the spoonful, without intending to remove it completely, but making sure that some of it is left to facilitate the melting, knowing that when the glass is taken out to the water it will release all the surplus salt. In this way, the "casco" will come out better and it will be useful for the compositions that will be refined and worked as it will be said in number three.

Another note
Since the composition at the beginning of this sheet is not sufficient to fill up the crucibles, it will be necessary to supplicate it by adding, instead of 250 pounds of frit, five hundred; instead of four pounds of nitrate, eight: and instead of five ounces of manganese, ten of it.

Another note
If after melting the first part of the crucible we notice that the glass still has a greenish or bluish color, we will add manganese prudently and in a way that keeping track of the manganese that has been added, we never add so much that it surpasses four ounces for every one hundred pounds of composition.

Final note
[crossed out: This composition alone is not enough to fill up the crucibles and for this reason it is necessary to double the quantities that were annotated at the beginning].

April 27 of 1820
Nº 3º

Compositions of "casco" and frit to refine and make objects
We measure two hundred pounds of frit which are eight "arrobas" ….. 200 pounds
Of potassium nitrate, four pounds ………………………………………………… 004 pounds
Of manganese, half a pound, eight ounces …………………………………….. [crossed out: illegible]
Of "casco," eight "arrobas" twenty pounds which are two hundred and twenty pounds………………………………………………………………………………………. 220 pounds
All of this is well mixed and divided into three parts, so that the first part can be placed into the mortars. Once this is well molten we add the second part; and when this one is well molten, we add the third one.
From the moment we start melting the first part, we have to keep enough live fire that is uniform, so that the melt will be well made.
When the melt of all the three parts that are added to the crucibles is well done, then we lower a little the fire of the furnace.
I repeat that we know that the melt is well done when the bubbles or "eyes" that the testers which are withdrawn have are small, about half a line in size. This is when the fire of the furnace is

lowered down a little in order to stop the boiling of the crucibles, and during this repose, all the impurities come up to the surface of the crucible along with the salts and foam that gather there. This repose should last for either four, six or ten hours depending on the aspect that the glass has, because if after four hours of letting it rest we can see that the glass is refined, then the repose should not last any longer. I say the same if this happens after six or ten hours.

Once the glass is refined, we remove the salt that floats on the surface by the spoonful. Immediately afterwards, we clean the surface of the glass in the crucible with a "pumel" and a blowpipe. Then we can begin working with the glass.

While making objects we must keep in mind two things. First, that the gather of glass that is taken with the tip of the blowpipe to form the "pumel" should be slightly cooled down in water so that we prevent the blowpipe from rusting too much and the tip to melt down. And second, that all the pieces that are made must be kept red hot during their elaboration, and they should also be hot when they are transferred to the tempering furnace so that they are annealed well and they do not break.

For this, it is also necessary that the main part of the tempering furnace in which the finished objects are placed is at a good heat. To this purpose, we must light up the fire in the tempering furnace ten or twelve hours before we begin to work, and we must make sure that the fire is rising during the first or primary lay out of the pieces, when we begin to place them inside.

I say the first or primary lay out because it is assumed that the extreme of the tempering furnace, or the opposite extreme from which the flame comes in should be colder, so that it can receive the pieces in the order that they get into the tempering furnace besides the flame for their annealing, and once they reach that stage, they have to be removed to make room for the new pieces, and so that all of them successively and in order are placed first by the flame of the tempering furnace, then a little further away, and finally at the coldest end of the tempering furnace.

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