## An Introduction to the History and Technology of Ancient Glass Production

Anastasios Antonaras

Glass was one of the first substances invented, possibly as a very fortunate accident during experimentation with glazed pottery or faience. This advance probably took place sometime in the third millennium BCE, in all likelihood in Mesopotamia, and the first objects—monochrome, polychrome translucent, or opaque—were produced in Mesopotamia and Egypt. The indications for glassmaking in Egypt are rare but clear. Initially, simple beads and, later on, decorative elements and inlays were for a very long period the only glass creations, while vessels—polychrome opaque ones—are known only from the fifteenth century BCE onward.

Colored glass was available to glass workshops operating in major urban centers in Mesopotamia, Egypt, and the Aegean—with clear stylistic and color differences between them—thanks to the long-distance trade of glass ingots. The fact that all three regions’ workshops were housed in palaces or temples highlights the material’s elite status, and in this era the use of glass vessels was extremely restricted, occurring only in the most affluent social circles. In the Mycenaean world in the second half of the second millennium BCE, many beads and pendants of dark blue and only very rarely white glass were used ([2003.214.1](#num)–[.17](#num), [2004.15.1](#num)–[.7](#num)) and a few small unguentaria made with mosaic technique are also noted. In eighth-century BCE Assyria, colorless transparent glass was made for the first time and used for the production of vessels ([2004.16](#num)).[[1]](#endnote-2)

The raw materials required for the production of glass are silica, which is derived from sand; soda (sodium carbonate), of which the main source in historic times was natron from Wadi Natrun in northern Egypt;[[2]](#endnote-3) and calcium, either as limestone or from the crashed shells already present in sand. Glass was colored through the addition of metallic oxides (iron, manganese, cobalt, copper, lead, antimony).[[3]](#endnote-4)

Glassmaking—that is, the production of glass out of raw materials—and glassworking, the forming of objects out of preexisting glass, constituted two distinct processes of ancient and medieval glass production that took place in different regions and at different times.[[4]](#endnote-5) For example, glass produced in the mid-second millennium BCE in the East—that is, on the Syro-Palestinian coast and in Egypt—was transported in ingot form and sold in distant western regions, where it could be used at any time, depending on the needs and intentions of the glassworker who bought it.

Glass workshops, although they were not supposed to operate within city walls, at least from Roman times onward have been archaeologically attested in almost all cities and towns of the Empire, either near the city walls (outside or inside them), or often housed in abandoned public spaces and buildings at the center of the cities, occasionally within workshop quarters but also around military camps.[[5]](#endnote-6)

In Classical Greece, core-formed multicolored vessels, mainly unguentaria, and miniature replicas of tableware were produced from the sixth century BCE onward. These apparently were expensive items, meant only for gods, kings, and the highest ranks of society. In the fourth century BCE in Greece and the Near East, colorless transparent glass was reintroduced and fashioned into small objects and fancy tableware vessels apparently used in official or ceremonial banquets. During the Hellenistic period (fourth–first centuries BCE), technical and artistic advancements occurred in glassworking, but glass vessels remained exquisite products, like tableware, almost exclusively drinking vessels, such as bowls, and a few pouring vessels, such amphoras, which were still intended for elite users. It was only in the late Hellenistic period (second–first centuries BCE) that drinking vessels of simpler form and decoration started appearing in bigger numbers, for the first time produced for upper middle-class users.

The invention of the glassblowing technique in the first century BCE for the first time made glass objects even more accessible to wide parts of society and led to the prevalence of glass objects in almost every middle-class household. All classes of tableware were amply produced in glass: drinking vessels (bowls, beakers), vessels for presenting and offering food (dishes, plates, trays), and vessels for pouring liquids and drinks (jugs, decanters, flasks/bottles). Unguentaria appear in a great variety of shapes and sizes, containing perfumes as well as cosmetic, medical, and religious substances.

For the first time, then, the storage, preservation, and trade of various products, even in large quantities, could be conducted in bulky, completely utilitarian glass vessels. Furthermore, from the third–fourth centuries CE onward a new use of the transparency of glass was devised and glass vessels were used as lamps. Some forms of tableware—bowls and beakers—were altered to serve as lamps, or other special forms were formed to cover the needs of society for lighting, which from late antiquity onward were mainly accomplished by glass containers.

Throughout the Late Antique, Byzantine, and medieval periods, and according to social, economic, and commercial fluctuations, glass retained these uses. Glass served people in various ways in their everyday life, in official and important occasions, and finally accompanied them to their graves, where these fragile items were protected from breakage and the consequent recycling that was widely occurring, thereby offering us a better glimpse of the wide variety of shapes, sizes, and colors of these products.

## Glass-Forming Techniques

The common feature among all ancient and modern glass-forming techniques is that they make good use of the fact that glass becomes liquid if adequately heated. Then, with the help of gravity—and frequently also of rotation, which helps to maintain an object’s symmetry—the molten glass is formed into the desired shape, using appropriate—and very basic—tools. During the Hellenistic era there was a push to explore the use of a variety of forming techniques. Blowing became the dominant technique after the first century CE.

### Core-Forming

Core-forming involves the formation of a vessel with the help of a metal rod, the tip of which has been covered with a core made of a mixture of inorganic and organic materials.[[6]](#endnote-7) The exact details of this process are not yet fully known and more than one theory exists about it.[[7]](#endnote-8) It seems that the core is coated with a layer of crushed glass mixed with a little water; this procedure is repeated as many times as necessary to obtain the required thickness. The core is then inserted in the furnace opening, where the molten glass fuses and the vessel is formed. Thin threads of glass in contrasting colors with the body are wound around the vessel and dragged up and down, forming festoons, zigzags, or feather-like motifs (fig. 1).[[8]](#endnote-9)

The earliest recorded appearance of the core-forming technique was in fifteen-century BCE Mesopotamia and during the second half of the second millennium BCE in Egypt, where local glassworking production appeared as well. Egyptian glassworking is different in the higher quality of the glass employed, and the greater variety of vessel shapes and decorative themes used. The high quality of the vessels can be connected to the fact that glass was made in workshops associated with royal palaces; such vessels were made exclusively for the use of royalty and high nobility.[[9]](#endnote-10) The Egyptian production of core-formed vessels, which include bottles, jugs, amphoriskoi, krateriskoi, beakers, flasks, cups, and other special shapes, has been organized into six major groups or workshops and the Getty collection comprises examples of three of them.[[10]](#endnote-11) Egyptian glass production of the Pharaonic era is represented in the JPGM collection by amphoriskoi ([2003.146](#num), [2004.3](#num)), a flask ([2003.147](#num)), a lentoid flask ([2003.148](#num)), and a krateriskos ([2004.2](#num)) dated in the middle of the second millennium BCE. Between the tenth and the eighth centuries BCE, when they reappear in Mesopotamia, the manufacture of core-formed vessels in Egypt appears to have ceased.[[11]](#endnote-12)

Very few sites and little infrastructure for glassworking practices are preserved between the discovery of glass in ancient Mesopotamia and the Roman era. Nonetheless, some information can be extracted from written sources, from excavated artifacts related to glass production, and from the products themselves. For instance, Mesopotamian glassmaking recipes, preserved in cuneiform texts, inform us that there were already three types of glassmaking furnaces being used.[[12]](#endnote-13) Also, the Hurrian site of Nuzi has yielded the earliest remains of glass manufacturing, dated in the second half of the fourteenth century BCE.[[13]](#endnote-14) Finds from fourteenth-century BCE Tel el-Amarna in Egypt have been identified as primary glassworking installations, as were finds from thirteenth-century BCE Qantir, while wall decoration at Karnak from the period of Tuthmosis III (1479–1425 BCE) seems to show blue glass ingots.[[14]](#endnote-15) Moreover, preserved glass ingots provide information regarding the form of furnaces and the materials used in firing; they show that glass was manufactured in small-scale crucibles of various shapes, either curved or rectilinear.[[15]](#endnote-16) These ingots, discovered in excavations of shipwrecks, also prove that the primary production of glass was already taking place in the middle of the second millennium BCE, in locations and regions that were far distant from the areas in which that glass would eventually be formed into vessels or other solid objects. For example, the glass ingots found in the ca. 1400 BCE shipwreck at Ulu Burun off the western coast of Turkey may have been made in Egypt. Shipped to Greece, such ingots were formed into blue glass beads ([2003.214.1](#num)–[.17](#num), [2004.15.1](#num)–[.7](file:///C:\Users\Tassos\AppData\Local\Temp\pid-9356\2003.186)) by the Mycenaeans.[[16]](#endnote-17) The oldest excavated glass workshop, safely dated in the fourth century BCE, was active in the city of Rhodes, Greece, where both vessels and beads were produced.[[17]](#endnote-18)

Core–formed vessels appear for the first time in the Aegean Sea region in the sixth century BCE, quite probably having been produced on the island of Rhodes. These are genuinely innovative products that do not imitate or evolve from known shapes in the repertoire of Mesopotamian and Egyptian core-formed vessels, but rather render the shapes of contemporaneous Greek clay vessels, in particular alabastra ([2003.180](#num), [2003.181](#num), [2003.182](#num), [2003.183](#num), [2003.184](#num), [2003.185](#num), [2003.186](#num), [2003.189](#num), [2003.190](#num), [2003.196](#num), [2004.5](#num), [2004.6](#num)), amphoriskoi (small amphoras) ([2003.178](#num), [2003.168](#num), [2003.169](#num), [2003.171](#num), [2003.172](#num), [2003.173](#num), [2003.170](#num), [2003.175](#num)), aryballoi ([2003.174](#num), [2003.177](#num), [2004.4](#num), [2003.176](#num)), and oinochoai/juglets ([2003.179](#num), [2003.166](#num)). It is believed that they were used as unguentaria, intended for aromatic and cosmetic substances.

The earlier examples are dated in the period between the middle of the sixth to the end of the fifth century BCE and appear in large numbers in Rhodes, Macedonia, the Aegean islands, and Italy.[[18]](#endnote-19) Two groups are easily discerned among these early examples, those made of dark blue and purple glass decorated with applied white, yellow, and turquoise threads (alabastra [2004.6](#num), [2003.190](#num), [2003.196](#num), [2003.185](#num), [2003.182](#num), [2003.183](#num), [2003.184](#num), [2003.189](#num), [2003.186](#num); amphoriskoi [2003.168](#num), [2003.169](#num), [2003.171](#num), [2003.172](#num), [2003.173](#num), [2003.170](#num), [2003.175](#num); aryballoi [2003.174](#num), [2003.177](#num), [2004.4](#num), [2003.176](#num); oinochoai [2003.179](#num), [2003.166](#num)) and those made of milky glass decorated with purple threads (alabastra [2003.180](#num), [2004.5](#num); amphoriskos [2003.178](#num)). Core-formed vessels, like juglets with a spiky appearance ([2003.164](#num)), small bowls, and alabastra were also produced in the Etruscan world from the middle of the seventh century BCE until the first decades of the sixth century BCE.

A second group of core-formed vessels appears after the early fourth century BCE; they were produced until the third century BCE. These vessels probably came from more than one workshop and are found predominantly in mainland Greece, as well as in central and southern Italy and, less often, on the Greek islands. The earlier examples of this group repeat the vessel types of the first group, that is, alabastra ([2003.193](#num), [2003.187](#num), [2003.191](#num), [2004.7](#num), [2004.8](#num), [2003.188](#num), and possibly [2003.192](#num)), amphoriskoi, aryballoi, and juglets ([2003.165](#num), [2003.167](#num)), with some differences in shape and decoration, following the morphological evolution of their clay counterparts. Sometime later completely new shapes appear, such as the hydriske, the unguentarium ([2003.203](#num)), and the lentoid aryballos.[[19]](#endnote-20)

The third group of core-formed vessels is dated to the period between the second century BCE and the early first century CE; the centers of production appear to have been in Cyprus and on the Phoenician coast. What sets apart this group from the previous two is that the alabastra ([2003.194](#num), [2004.22](#num), [2003.195](#num), [2003.197](#num), [2003.198](#num)) and the amphoriskoi ([2003.200](#num), [2003.201](#num), [2003.202](#num), [2003.204](#num), [2003.199](#num)) it includes are different in shape from the older ones, following the shapes of contemporaneous ceramic vessels.[[20]](#endnote-21)

### Rod-Forming

In this method, a glass object is constructed around a metal mandrel (fig. 2, Rod-forming technique). It was originally intended, and quite often was used, for making beads, pendants, and bracelets. Additionally, it allowed the construction of the tall, narrow vessels that first appeared in Egypt in the fourteenth century BCE,[[21]](#endnote-22) in the Near East between the sixth and fourth centuries BCE,[[22]](#endnote-23) and in the Hellenistic period.[[23]](#endnote-24) Rod-formed cylindrical unguentaria known as “kohl tubes”—probable Iranian products dating to the fifth century BCE—are represented in the JPGM collection by three ornate examples ([2003.160](#num), [2003.162](#num), [2003.163](#num)). Moreover, in the fourth and fifth centuries CE this technique was widely used on the Syro-Palestinian coast to form small-size vessels out of brightly colored opaque glass—usually black and turquoise ([2003.470](#num), [2003.469](#num), [2003.468](#num)),[[24]](#endnote-25) with a very few known later examples dated in the seventh and eighth centuries ([2003.463](#num)).

### Casting

Casting in open, one-piece molds was the technique used for the production of the earliest glass objects, such as Egyptian inlays ([2003.150](#num)–[2003.154](#num)) and Mycenaean beads ([2003.214.1](#num)–[.17](#num), [2004.15.1](#num)–[.7](#num)). Casting in closed molds is the technique of forming a glass vessel or a solid object like a sculpture ([2003.356](#num), [2003.357](#num)) through the use of a mold, which is filled with cullet (crushed residual glass) (fig. 3, cast glass, lost wax technique). It is based on the lost-wax casting technique, widely employed in metalworking.[[25]](#endnote-26) Cullet was used because it was not possible through ancient pyrotechnologies to achieve temperatures high enough for the glass to melt and be poured into the mold. An early example in the collection of casting and drilling takes the form of an alabastron ([2004.16](#num)).

During the Julio-Claudian era, single-colored, brightly hued glass vessels appeared that had the exact shame shape as the clay and silver vessels of that time.[[26]](#endnote-27) Although it was once believed that they were cast,[[27]](#endnote-28) more recent research indicates that they may have actually been made using a rotary pressing variation (see below) ([2003.232](#num), [2003.233](#num), [2003.234](#num), [2003.235](#num), [2003.236](#num)).[[28]](#endnote-29)

### Slumping

Slumping is a technique used to form open-shaped vessels by slumping, or sagging, a disk of viscous glass heated in the furnace over a convex former mold or in a concave, open mold; the glass disk gradually slumps and takes the shape of the mold through gravity, with the glassworker’s appropriate tooling.[[29]](#endnote-30) This technique appears relatively often in the years before the invention of glassblowing, used for various vessel forms and production methods. What vessels formed by slumping have in common is the fact that human breath was not used in their production. Such vessels were formed by heating the glass and using either a simple, open mold or a bipartite, closed one. In addition, in the early first century CE, slumped and blown mosaic vessels—small- or medium-sized flasks and unguentaria—were produced, illustrating the transition to the free-blowing technique ([2003.277](#num)–[2003.293](#num)).[[30]](#endnote-31)

Mosaic vessels were made of bands and/or horizontal rod or cane sections of glass, known as florets ([85.AF.85](#num)–[2003.255](#num)). Masses of hot glass of the adequate colors were put together, tooled, and adhered, creating a wide and thick plaque with the desired motif in large scale in it. This plaque was reheated and pulled out for several meters, producing thus a rod of a much smaller diameter with the design all the way through. Thin discoid sections of these rods or canes were cut and used to form mosaic vessels and architectural and furniture inlays. The bands/cane lengths used were sometimes simpler monochrome or polychrome pieces and other times composite ones, forming intricate motifs, such as spirals, concentric circles, or rosettes. These pieces were heated on a flat surface; placed in contact with each other, they fused together and created a disk, whose perimeter was enclosed by a twisted polychrome—usually white and blue—glass coil. In order to give the mosaic vessel its final form, glassworkers then used the slumping technique on a convex former mold (fig. 4, slumping technique).[[31]](#endnote-32) It is possible that for some types of vessels, glassworkers used a bipartite mold, which was filled with discoid tesserae that had been cut from cylindrical canes. The mold was sealed and heated so that the tesserae would fuse. After the vessel was [[annealed]], it was internally polished on a lathe.

A long tradition of mainly monochrome glass inlays placed in cells cut into a wooden background flourished, especially during the Late Period in Egypt (712–332 BCE). They were used to decorate objects intended for religious or funerary purposes. Later, probably in Egypt or also in Italy, in about the late first century BCE through early first century CE, composite mosaic glass canes were produced which were cut into slices, forming small plaques. They thereby presented a complete miniature theme from fused together glass canes that were tooled to form the appliqué of the incrustation bearing the entire desired motive and pulled out and reduced to the desired minuscule size: geometrical patterns, floral motives, theatrical masks, fish, deities, and imitations of veined stones ([2003.266](#num), [76.AF.70.11](#num)). These plaques represent the most exquisite and technically refined glass products of the ancient world. They were used to decorate wooden objects, like caskets or boxes, framed with other monochrome or polychrome glass elements, probably used in rows of similar motives.[[32]](#endnote-33) A unique trimming of such a rod comprised of concentric layers of bright colored glass, which was pierced and used as a pendant, is in the JPGM collection ([76.AF.70.46](#num)). Florets and other sections of mosaic rods and canes were used for the creation of beads ([2003.259](#num)–[2003.211](#num)) representing geometrical patterns or human faces.

Millefiori vessels are recognized as a special type of mosaic vessel even though their forming process was not technically different. Millefiori-vessel tesserae were pieces of composite mosaic canes that had the shape of a flower in cross-section, known as florets. In the JPGM collection 2 dishes ([85.AF.85](#num), [2003.258.1](#num)) and 28 bowls ([85.AF.86](#num), [78.AF.32](#num), [2003.248](#num), [2003.249](#num), [2003.250](#num), [96.AF.288](#num), [76.AF.70.44](#num), [76.AF.70.21](#num), [76.AF.70.32](#num), [83.AF.28.10](#num), [83.AF.28.16](#num), [83.AF.28.6](#num), [83.AF.28.8](#num), [83.AF.28.18](#num), [83.AF.28.22](#num), [83.AF.28.11](#num), [83.AF.28.12](#num), [76.AF.70.36](#num), [83.AF.28.17](#num), [83.AF.28.4](#num), [2004.26.3](#num), [2003.258.5](#num), [2004.26.6](#num), [83.AF.28.14](#num), [83.AF.28.19](#num), [76.AF.70.18](#num), [76.AF.70.23](#num), [76.AF.70.24](#num)) are included.

The twisting network vessels of the reticella type are another category of mosaic vessel, whose forming technique was, however, different. They are made of a distinctive glass cane, composed of one or two thin threads of colored glass twisted onto or inside clear molten glass.[[33]](#endnote-34) The vessels were formed by firing and fusing together short canes of the type forming a disk, or by winding a long, hot cane around a former mold with the help of a long, wide, flat wooden tool, the paddle, while the rim was formed by attaching a twisted, bichrome coil.[[34]](#endnote-35) In the JPGM collection reticella mosaic vessels, include fragments of two bowls ([2004.26.7](#num), [2003.258](#num)).

Marbled mosaic vessels and gold-band mosaic vessels are formed in a similar way.[[35]](#endnote-36) A composite glass cane, with the desired motif formed along its length, was wound spirally on a flat surface. It was then pressed again at regular intervals so that an undulating motion would complement the spiral decorative motif, which resembled the veining of semiprecious stones.[[36]](#endnote-37) The vessel assumed its final shape through slumping in a former mold, a process that further distorted the decoration and rendered it even more intricate. In the JPGM collection marbled mosaic vessels include 4 bowls, 1 plain ([2003.253](#num)), and 3 ribbed ([72.AF.37](#num), [2004.25](#num), [76.AF.70.15](#num)); a lidded pyxis ([2003.256](#num)); and fragments of 6 unidentified vessel shapes ([76.AF.70.2](#num), [76.AF.70.4](#num), [76.AF.70.9](#num), [76.AF.70.19](#num), [76.AF.70.39](#num), [76.AF.70.33](#num)). In addition, there are 3 gold-band vessels, an alabastron ([2003.229](#num)), a pyxis ([2003.231](#num)), and a flask ([2003.230](#num)). Furthermore, in the JPGM collection are striped mosaic vessels—that is, vessels made of lengths of mosaic canes—including an alabastron ([2004.21](#num)) and six bowls ([2004.23](#num), [2003.246](#num), [2003.251](#num), [2003.252](#num), [2003.247](#num), [2004.24](#num), and eight vessels of unidentified shape [83.AF.28.27](#num), [2004.26.7](#num), [2003.258.6](#num), [2004.26.9](#num), [2003.258.3](#num), [2003.258.4](#num), [2004.26.8](#num), [2003.258.2](#num)).

Some closed-shaped vessels were also formed by firing a blank disk composed of bands of glass. The disk was heated and slumped on an oval form-mold made of plaster; gravity allowed its bottom part to acquire a conical shape. This part was then compressed into a narrow cylindrical neck with the help of a paddle. At the end of the process the form was crushed and its remains were removed from the inside of the vessel.[[37]](#endnote-38) For examples in the JPGM collection see the gold-band alabastron ([2003.229](#num)) and the flask ([2003.230](#num)). In the case of gold-band mosaic vessels, a band made of a sheet of gold leaf encased between two layers of transparent glass was used together with other composite bands, each made of two or three different colors of opaque glass. In the JPGM collection, 3 gold-band vessels appear, an alabastron ([2003.229](#num)), a pyxis ([2003.231](#num)), and a flask ([2003.230](#num)).

### Rotary Pressing

This technique is almost the same as that of mold pressing, that is, the technique of forming an object by pressing viscous glass into an open mold made of plaster or clay; the only difference is that the former mold is placed on a potter’s wheel so that it can be rotated.

The desired decoration is generated in intaglio on the inside of a plaster mold or former; the mold/former is then placed on the potter’s wheel and preheated viscous glass is pressed onto its walls with a plunger that thus shapes the interior of the vessel. The mold is shattered in order to release the finished vessel.[[38]](#endnote-39) It is very likely that cameo glass vessels were at least partly formed through this technique ([84.AF.85](#num), [85.AF.84](#num), [2003.354](#num), [96.AF.289](#num)).[[39]](#endnote-40)

The ribbed bowl ([2003.221](#num)–[2003.225](#num)) is a widely circulated vessel form that was produced by a variation of this technique. Even though there are different theories as to the technique that was used to form such bowls, the prevailing one today is the following: A preheated disk of glass is placed on a form in order to receive its final shape, while at the same time it is pressed radially with a rod in order for the relief ribs to be created.[[40]](#endnote-41) After this is done, the vessel is momentarily reinserted in the furnace and the heat to which it is exposed polishes its exterior. The vessel’s interior, as well as the exterior of its rim, is cold-polished on the lathe, a process which leaves visible traces in the form of fine striations (fig. 5, rotary-pressing technique of a ribbed bowl).

A class of single-colored, brightly hued vessels appeared in the late first century BCE and were produced into the first half of the first century CE; their shape was identical to that of contemporary clay and silver vessels.[[41]](#endnote-42) These used to be considered as cast[[42]](#endnote-43) but more recent research suggests that they were produced through a variation of rotary pressing.[[43]](#endnote-44) In the JPGM collection five bowls are included ([2003.232](#num), [2003.233](#num), [2003.234](#num), [2003.235](#num), and [2003.236](#num)).

Finally, another simple vessel-forming technique, heavily influenced by pottery making, consists in placing a heated mass of glass on a potter’s wheel and forming the vessel’s vertical walls by simultaneously pressing a plunger in the center of the glass and using a paddle on the exterior. These two tools substitute for the potter’s hands. It is thought that this technique was invented in Crete in the early second century BCE; it was used in the production of a particular type of pyxis (fig. 6, rotary-pressing technique for a Cretan pyxis).[[44]](#endnote-45)

### Free-Blowing

The technique of free-blowing involves the inflation and further shaping of molten glass through the use of human breath channeled through a heat-insulated pipe. According to Pliny, glassblowing, or flatu figurare, that is, “shaping by breath,” was one of the three techniques that made Sidon a famous glassworking center.[[45]](#endnote-46) The technique was invented in the first half of the first century BCE somewhere in the Syro-Palestinian area, where there was already a centuries-long tradition in glassworking.[[46]](#endnote-47) Around the middle of the first century CE free-blowing began to spread beyond the Syro-Palestinian region to Italy, Switzerland, and Dalmatia.[[47]](#endnote-48)

The period of the technique’s spread and popularization coincided with the Augustan age—and the resulting political calm and economic flourishing. Moreover, this political situation made possible easy and fast communication between the different provinces. The economic boom in Italy attracted tradesmen and workmen from all over the Empire and especially from the eastern provinces. The quality and quantity of early blown vessels that have been preserved in the West, in contrast to the relative scarcity of such finds in the East, would seem to support this hypothesis. It appears that the blowing technique was perfected in Italy and—as documented also in historical sources,[[48]](#endnote-49) particularly in Rome, where glassworkers from the East—Sidonians especially—relocated for financial reasons.[[49]](#endnote-50)

The free-blowing technique reached maturity with the help of three developments: the invention of the closed, vaulted furnace, in which it is possible to melt glass in a clay crucible or tank, that occurred by the third quarter of the first century CE at the latest;[[50]](#endnote-51) the invention of the blowpipe, a hollow rod—probably at first made out of clay and later of metal—through which the vessels were blown;[[51]](#endnote-52) the use of the blowpipe or of some other, solid iron rod (a pontil), onto which the half-finished vessel is transferred in order for the vessel’s rim to be formed while it is still hot (fig. 7, free-blowing technique).

The innovative discovery of blowing rendered the production of glass vessels much easier and more economical, as each vessel could be made with much less glass and the formation process was much swifter in comparison with earlier techniques. Strabo illustrates this shift clearly when he writes that in the second half of the first century CE one could buy a glass vessel for just one copper coin.[[52]](#endnote-53) This resulted in the devaluing of glass objects in the economic and aesthetic system of Roman society. The use of glass then spread throughout all social strata, and geographically it reached the most remote parts of the Roman Empire and even beyond. Glass vessels also took on new functions, such as the transport and storage of liquid and solid products in large quantities. Gradually, everyday, utilitarian glass objects began to be sold by the pound.[[53]](#endnote-54) Blowing and technical processing in general did not significantly add to the price of glass as a raw material. This clearly points to the simplification of the forming process, as well as to the widespread circulation of glass products, even though they are known to have been ten times more expensive than clay vessels of equal size.[[54]](#endnote-55)

Free-blown vessels present the largest group among the JPGM vessels, with 148 examples. Among them 4 plates and dishes ([2003.387](#num), [78.AF.33](#num), [76.AF.29](#num), [2003.351](#num)), 23 bowls and cups ([2003.290](#num)–[2003.455](#num)), 10 beakers ([96.AF.320](#num)–[2003.444](#num)), 1 skyphos ([2003.361](#num)), 1 kantharos ([84.AF.30](#num)), 2 amphorae ([2003.402](#num), [78.AF.18](#num)), 14 flasks ([96.AF.56](#num)–[2003.449](#num)), 5 guti ([2003.245](#num)–[2003.447](#num)), 18 jugs ([2003.476](#num)–[2003.288](#num)), 1 bottle ([71.AF.79](#num)), and 28 unguentaria ([2003.297](#num)–[2003.306](#num)) (12 handleless, 3 sprinklers, 11 amphoriskoi/handled, 2 oinochoae).

### Mold-Blowing

Mold-blown vessels—vessels made by blowing a heated mass of glass into a previously manufactured container, on the inside of which is an intaglio decoration that becomes imprinted on the exterior surface of the vessel being formed—were always a rarity (fig. 8, mold-blowing technique). Even during the time of the technique’s greatest popularity, in the first century CE, such items represented only a small fraction of the total glassworking production. This was an important technique from an aesthetic perspective, but quantitatively contributed only very little to the totality of glass production.[[55]](#endnote-56) The use of this technique with glass presents special difficulties. Unlike clay, glass does not shrink when cooling; it inserts itself in the most detailed points of the mold’s decoration, where it remains and hardens. It was therefore necessary to use two- and three-part clay or plaster molds[[56]](#endnote-57) that were casts of metal or glass originals. The molds were repaired or fully replaced relatively frequently, because upon coming into contact with the hot glass, they were subjected to a strong thermal shock that wore them out after a short period of use.

Mold-blowing, referred to as “argenti modo caelere,” according to Pliny, is one of the three techniques that made Sidon a renowned glassworking center.[[57]](#endnote-58)

The use of multipart molds was invented and developed on the Syro-Palestinian coast, probably in an effort to form glass products that imitated metal prototypes with forged-decorated surfaces.[[58]](#endnote-59) Mold-blowing started to be used commercially during the time of Augustus; its development in the western part of the Roman Empire began probably around the middle of the first century CE, with a focus on the production of tableware.[[59]](#endnote-60) It remained popular until the end of the Flavian era (69–96), when it was superseded by the facet-cutting technique. Mold-blown vessels continued to be made, albeit sporadically, until the fourth century CE, using a very restricted set of decorative themes that mostly depicted human heads.[[60]](#endnote-61) Polygonal *eulogia* vessels, meant to hold sanctified liquid, water, or oil from the Holy Land, appeared in the eastern Mediterranean in the late sixth and early seventh centuries CE, bearing religious decorations consisting of Christian and Judaic motifs.[[61]](#endnote-62)

Mold-blown vessels represent a large group among the JPGM vessels, with 59 examples. Among them are 10 bowls and cups ([2003.474](#num)–[2004.34](#num)), 6 beakers ([85.AF.83](#num)–[2003.323](#num)), 6 flasks ([2004.36](#num)–[78.AF.37](#num)), 9 jugs ([85.AF.320](#num)–[2003.344](#num)), and 28 unguentaria ([2003.297](#num)–[2003.306](#num): 12 handleless, 3 sprinklers, 11 amphoriskoi/handled, 2 oinochoae).

### Dip Mold–Blown

Dip mold–blowing is a variation on the mold-blowing technique used to produce decorated vessels, fully formed in a mold, with only details like the handle or rim shaped freehand. It comprises vessels that were produced by free-blowing, but whose decorations were first formed in a mold. These vessels acquired their relief decoration during the early stages of blowing by being inserted into a mold or a ring with a relief interior. Then, using free-blowing, they were given their final shape. As a result, the decoration expanded, covering a larger area and thus faded out and extruded less (fig. 9, dip-mold blowing technique). Throughout the Roman era, dip mold–blowing was employed at various periods, especially during the fourth and fifth centuries CE.[[62]](#endnote-63) Additionally, it has been shown that, at least in some cases, engraved decorations were first roughly indicated by blowing the vessel in the appropriate mold before these blanks were completed by wheel-cutting.[[63]](#endnote-64)

Dip mold–blown vessels represent a small group among the JPGM vessels, with 11 examples. Among them appear one bowl ([2003.339](#num)), one beaker ([2003.435](#num)), one amphora ([2003.414](#num)), eight flasks ([2003.429](#num)–[2003.342](#num)).

## Decorative Techniques

### Wheel-Cutting/Engraving

This technique involves the removal of part of the mass of glass from a vessel with the help of a bowdrill. It was used to partially form some vessels during Classical Greek and Hellenistic times in the second half of the first millennium BCE.[[64]](#endnote-65) During the Roman period all the ways of creating engraved decorations known today were in use. These engraved vessels are the vessels known in the historical sources as τορεύματα (works in relief);[[65]](#endnote-66) their decorations were formed with a rotating stone or metal lathe and pointed, metal tools.[[66]](#endnote-67) The use of this technique linked glass and glass decorating with minor-object manufacture in general and with the production and decoration of silver and bone vessels and objects in particular.[[67]](#endnote-68) The decoration comprised mainly of geometrical patterns, faceting, inscriptions, floral motifs, and figurative scenes. Interesting examples in the JPGM collection include among the others a plate ([2003.351](#num)), bowls ([96.AF.320](#num), [2004.38](#num)), a jug ([2003.346](#num)), and a flask ([2003.350](#num)).

### Cameo Glass

The cameo technique also became linked with engraving. It was traditionally believed that cameo vessels or objects were produced through the repeated blowing, or “casting,” of different-colored layers of glass, that is, a darker background was coated with a white layer, a process repeated when more than one color was used. According to this view, the desired motif was carved into the outer layer through cold-cutting and cold-polishing, thus revealing around it the layer of glass below, a dark-colored background, against which the motif carved on the lighter-colored, upper layer would stand out. However, current scientific opinion holds, more convincingly, that basically the decoration was impressed on the vessel at the very moment of its formation, which occurred through rotary pressing in a mold. In the mold the different-colored plastic elements of the decoration were filled in advance with wet crushed glass, which melted and fused as the semi-viscous glass that would form the inner layer of the vessel body was pressed in (fig. 10, rotary pressing technique for a cameo vessel).[[68]](#endnote-69)

Very few vessels with cameo decorations have been preserved; most surviving specimens are dated to the late first century BCE and the first half of the first century CE.[[69]](#endnote-70) The cameo technique, simplified and executed by wheel-cutting, is revived in the fourth century. These late products differ from the earlier examples in that their body is made of more translucent glass and their decoration is flat with vertical edges.[[70]](#endnote-71)

In the JPGM collection there are four cameo vessels, and among these are two of the most spectacular extant examples, a two-handled footed bowl, or skyphos ([84.AF.85](#num)), and a small flask ([85.AF.84](#num)). The other two examples are fragments of another skyphos ([2003.354](#num)), and an unidentified vessel ([96.AF.289](#num)).

### Application of Plastic Elements

Decoration with applied plastic threads and coils of varying diameters constitutes the oldest decorative technique in glass-working, known since Pharaonic, Classical Greek, and Hellenistic times, and still in use during Roman times as well. In cases where the thread is attached to the vessel and marvered before the latter acquires its final dimensions, it is fully incorporated into the vessel’s surface and, provided that it is thick enough and appropriately placed, it may resemble the veining in stone vessels. In the first century, moreover, marvered and flattened threads, usually white ones on dark-colored vessels, are combined with pressed ribs to create the very particular vessels that are known by the German term “zarten Rippenschalen” ([2003.226](#num), [2003.227](#num)).[[71]](#endnote-72) Usually, however, the thread is attached after the vessel has acquired its final dimensions and therefore remains a relief decorative element.

In general, there can be discerned the following types of applied elements: (1) Oblong elements, finer threads, and thicker coils, left in relief (flasks and unguentaria [2003.420](#num), [2003.426](#num), [78.AF.19](#num), [2003.432](#num)) or marvered flush on the surface of the vessel ([2003.428](#num)). In the second century CE a particular technique known as snake-threading involved the application of thick, flattened threads that bear a simple geometric motif in relief on their surface ([96.AF.56](#num)). (2) Circular elements, plain, amorphous, or circular blobs that were either left in relief (bowls [2003.454](#num), [2003.455](#num)) or marvered flush (modiolus [2003.290](#num), aryballos [2003.292](#num), amphoriskos [2003.291](#num)), and relief decorative medallions.

### Gold-Glass, or “Fondi d’Oro”

The gold-glass technique first emerged during the Classical Greek period, used in decorative inlays for couches, thrones and statues,[[72]](#endnote-73) while in Hellenistic times it was used for the decoration of vessels.[[73]](#endnote-74) It appears to have been forgotten or to have fallen into disuse until the fourth century CE, when it reappeared.

The exact shapes of the vessels on which this technique was applied are not known since no whole vessels have survived. The extant specimens consist of flat vessel bottoms that were discovered, almost in their entirety, embedded in the plaster that sealed tomb openings in the Roman catacombs. Overall, there are known examples of Christian, Jewish, and pagan themes used in the decorations. Among other hypotheses, it has been assumed that such vessels were produced in order to be used as keepsake gifts on formal occasions, such as weddings and anniversaries of the assumption of public office.[[74]](#endnote-75)

Specific technical details regarding this decoration method remain unclear. In general, it refers to the attachment of a thin sheet of gold leaf to the inside bottom of an open-shaped vessel. The desired theme is engraved on the gold, while in some cases color is added to emphasize particular details. Subsequently a second [[paraison]] of glass is blown inside the vessel, which has already been adequately reheated so that it does not fracture due to thermal shock. The new layer of glass attaches itself to the walls of the vessel, thus sealing and protecting the decoration between two layers of translucent glass.[[75]](#endnote-76) This technique is used, both during this period and in the sixth century CE, for the production of tesserae as well as of plaques and crustae of opus sectile wall revetments.[[76]](#endnote-77) In the JPGM collection are two nineteenth-century replicas of gold-glass bowls ([2003.296](#num), [83.AK.29](#num)).

### Indentations

While the vessel is still hot it is decorated around its exterior with impressions that are probably intended to imitate the look of forged metal, the more valuable prototypes of glass vessels; the indentations are formed by simple thrusts with the help of pucellas. The same technique was also occasionally applied on clay vessels of the same period.[[77]](#endnote-78) The vessel body thus becomes sometimes almost cube-like and other times corrugated in shape. This technique, already used for free-blown vessels since the second half of the first century CE,[[78]](#endnote-79) becomes most widespread between the second and fourth centuries CE ([2003.412](#num), [2003.408,](#num) [2003.409](#num)).[[79]](#endnote-80)

### Pinching

Protrusions of various sizes are created on the surface of the glass vessel with the help of pincers; these projections are usually spread all over the lower part of the vessel body ([2003.436](#num), [2003.449](#num), [2003.438](#num)) and sometimes form toes ([2003.244](#num), [2003.285](#num)) or a ring that acts as a substitute for a base ([2003.448](#num)). These protrusions are usually flat; they have a small indent in their middle that is sometimes perforated because of the pressure exerted by the pincers.[[80]](#endnote-81)

This decorative technique appears in the eastern Mediterranean at the end of the second century,[[81]](#endnote-82) becomes more widespread from the fifth century on, and remains in use until the eighth century, at least in Jordan and in the Syro-Palestinian area ([2003.477](#num), [2003.437](#num), [2004.42](#num)).[[82]](#endnote-83) Pinching was also used for the shaping of scalloped rims, such as in the case of a bowl in the JPGM collection ([78.AF.22](#num)).

A technique that produces similar results, but is nonetheless different in terms of production, was used on vessels that have thicker, elongated protrusions, called “fins,” that are more regularly formed and arranged. In all likelihood, the fins in this case were created through mold-blowing. This technique appears around the third century CE[[83]](#endnote-84) and remains in use during the fourth century CE[[84]](#endnote-85) as well.

Finally another similar, but more intricate, decorative pattern, called “bifurcated” or “Fadendekor,” can also be produced by using pincers before the vessel has acquired its final size. In its simpler form the pattern is composed of vertical relief ribs that decorate the belly of the vessel, from base to shoulders. In its more complex version, the ribs are compressed at regular intervals, creating a rhomboid network.[[85]](#endnote-86)

### Bicoloring

Two or more different colors of glass were used in the production of vessels in Pharaonic Egypt, ancient Greece, the Roman world, and during medieval times. As part of the decoration of a vessel, the handles, the base, or even applied threads or blobs were formed of glass in a bright color that was different from the color of the vessel body.[[86]](#endnote-87) See, for example, core-formed alabastra and jugs ([2003.146](#num), [2003.160](#num), [2003.196](#num), [2003.165](#num)); mold-blown flasks ([2003.303](#num), [2003.314](#num), [2003.307](#num)); a dip mold–blown amphoriskos ([2003.414](#num)); and free-blown jugs ([2003.377](#num), [2003.450](#num), [2003.452](#num)), jars ([2003.394](#num), [2003.399](#num)), and an amphoriskos ([2003.402](#num)).

### Painting/Enameling

After the Late Classical Greek and Hellenistic periods (fifth–first centuries BCE), painting/enameling was used quite rarely as a decorative technique on glass vessels, occasionally alongside gilding.[[87]](#endnote-88) However, glass vessels with rich painted decorations do appear in relatively larger numbers in the last quarter of the first century CE. Pliny, who died in 79 CE, noted that in his time glass was the most adaptable material, useful even for painting.

The material used is a kind of enamel, pulverized glass of the desired hue mixed with a liquid. The mixture is painted on the vessel, which is then heated so that the decoration can fuse to its surface.[[88]](#endnote-89) Among the earliest Roman glass vessels decorated with enamel are bowls, such as [2003.294](#num), made between about 40 and 60 CE; these may be one of the forms of painted glass that attracted Pliny’s attention.[[89]](#endnote-90)

There are known examples of gilded vessels and plaques from the first and second centuries CE. In that period gilding was done after [[annealing]] and involved the application of gold leaf onto the surface to be decorated; the design details were then engraved with a pointed tool.[[90]](#endnote-91)

Finally, the decorations on some third-century vessel lids were cold-painted. To keep the decoration protected from damage—to which it was particularly susceptible because of its means of production—the design was painted in reverse on the inside surface of the lid, intended to be viewed through the glass.[[91]](#endnote-92)

<#>

All of the techniques described above continue in use during the third and fourth centuries CE,[[92]](#endnote-93) and they reappear occasionally later, such as during the Middle Byzantine period, between the tenth and thirteenth centuries CE.[[93]](#endnote-94)

1. {Stern and Schlick-Nolte 1994}, pp. 28–37; {Nicholson and Henderson 2000}, pp. 195–224; {Rehren 2021}. [↑](#endnote-ref-2)
2. {Nenna, Picon, and Vichi 2000}, p. 99. [↑](#endnote-ref-3)
3. {Pliny, Natural History} 36.62, 36.193. {Seneca, Epist.} 90.31, and 105. {Brill 1999}, vol. 1, pp. 15–17. [↑](#endnote-ref-4)
4. Glassmaking and glassworking had been considered distinct processes since the fourteenth century BCE, as evidence of glass ingots from the Ulu Burun shipwreck demonstrates. See {**Bass 1986}, pp. 281–282; {**Nicholson, Jackson, and Trott 1997}, pp. 143–153. [↑](#endnote-ref-5)
5. {Antonaras 2012}, pp. 10–15, wherein previous bibliography. [↑](#endnote-ref-6)
6. {Auth 1976}, p. 20; {Stern and Schlick-Nolte 1994}, p. 29. [↑](#endnote-ref-7)
7. {Stern and Schlick-Nolte 1994}, pp. 28–33. [↑](#endnote-ref-8)
8. {Harden 1981}; {Grose 1989}, pp. 109–125; {Stern and Schlick-Nolte 1994}, pp. 28–36, 37–44. [↑](#endnote-ref-9)
9. {Stern and Schlick-Nolte 1994}, p. 26. [↑](#endnote-ref-10)
10. {Nolte 1968}. [↑](#endnote-ref-11)
11. {Stern and Schlick-Nolte 1994}, pp. 28–37. [↑](#endnote-ref-12)
12. {Oppenheim et al. 1970}, pp. 69–71. [↑](#endnote-ref-13)
13. {Schlick-Nolte and Lierke 2002}, p. 19; {Vandiver 1983}, pp. 239–247. [↑](#endnote-ref-14)
14. For the finds from Amarna see {**Nicholson, Jackson, and Trott 1997},** pp. 143–153, pl. XVII; (Nicholson2007}, esp. pp. 125, 158. For the finds from Qantir see {Rehren and Pusch 1997}. For the finds from Karnak see {Schlick-Nolte and Lierke 2002}, pp. 17–22, figs. 3–4. [↑](#endnote-ref-15)
15. Barag 1985, pp. 107–113; {Stern and Schlick-Nolte 1994}, p. 20. [↑](#endnote-ref-16)
16. On Mycenean beads see {Nightingale 2002}, with further bibliography. [↑](#endnote-ref-17)
17. {Triantafyllidis 2000}**,** pp. 36–39, 193–195. [↑](#endnote-ref-18)
18. {Harden 1981}, pp. 58–99; {Grose 1989}, pp. 110–115. [↑](#endnote-ref-19)
19. {Harden 1981}, pp. 100–121; {Grose 1989}, pp. 115–122. [↑](#endnote-ref-20)
20. {Harden 1981}, pp. 123–141; {Grose 1989}, pp. 122–125. [↑](#endnote-ref-21)
21. {Stern and Schlick-Nolte 1994}, pp. 136 with rich bibliography on the Egyptian finds of the kind. [↑](#endnote-ref-22)
22. {Barag 1975}, pp. 23–26. [↑](#endnote-ref-23)
23. {Ignatiadou 2017}, p. 61; {Lierke 2001}, p. 183, fig. 10. [↑](#endnote-ref-24)
24. {Barag 1975}, p. 30, note 29; {Stern 2001}, p. 144, no. 78–81. [↑](#endnote-ref-25)
25. {Stern and Schlick-Nolte 1994}, pp. 50–52; {Lierke 2001}, pp. 183–184. [↑](#endnote-ref-26)
26. {Grose 1991}, p. 2; {Grose 1989}, p. 254. [↑](#endnote-ref-27)
27. {Stern and Schlick-Nolte 1994}, pp. 64–65. [↑](#endnote-ref-28)
28. {Lierke 1999}, pp. 58–59. [↑](#endnote-ref-29)
29. {Stern and Schlick-Nolte 1994}, pp. 68–71. [↑](#endnote-ref-30)
30. {Grose 1989}, pp. 261–262; {Stern and Fünfschilling 2020}, pp. 41–68. [↑](#endnote-ref-31)
31. {Stern and Schlick-Nolte 1994}, pp. 64–65, 68–69. Very enlightening on this matter are the illustrations in {Tait 1991}, pp. 219–221, where glassmaker B. Gudenrath recreates the process using modern equipment. [↑](#endnote-ref-32)
32. {Bianchi 1983a}; {Bianchi 1983b}; {Grose 1989}, pp. 351–358; {Stern and Schlick-Nolte 1994}, pp. 61–63, 360–364, 368–409; {Nenna 1995}; {Auth 1999}; {Mahnke 2008}; {Nenna 2010}, pp. 81–85. [↑](#endnote-ref-33)
33. {Stern and Schlick-Nolte 1994}, p. 54. [↑](#endnote-ref-34)
34. {Auth 1976}, p. 54, col. pl. 51; {Stern and Schlick-Nolte 1994}, pp. 65–66, 274–275; {Lierke 1999}, pp. 39–41. [↑](#endnote-ref-35)
35. {Lierke 1999}, pp. 61–66. [↑](#endnote-ref-36)
36. {Weinberg and McClellan 1992}, pp. 56–57, no. 48. [↑](#endnote-ref-37)
37. {Lierke 1999}, pp. 64–66; {Schlick-Nolte and Lierke 2002}, pp. 29–31. [↑](#endnote-ref-38)
38. {Lierke 1999}, pp. 32–36, 102–103. [↑](#endnote-ref-39)
39. {Lierke and Lindig 1997}; {Lierke 1999}, pp. 67–96. [↑](#endnote-ref-40)
40. {Stern and Schlick-Nolte 1994}, pp. 72–78. [↑](#endnote-ref-41)
41. {Grose 1991}, p. 2; {Grose 1989}, p. 254. [↑](#endnote-ref-42)
42. {Stern and Schlick-Nolte 1994}, pp. 64–65. [↑](#endnote-ref-43)
43. {Lierke 1999}, pp. 58–59. [↑](#endnote-ref-44)
44. {Lierke 1999}, pp. 37–39; {Stern and Schlick-Nolte 1994}, pp. 79–81. [↑](#endnote-ref-45)
45. {Pliny, Natural History} 36.193. For a detailed commentary on the passage, see {Stern 2007}, pp. 358–359. [↑](#endnote-ref-46)
46. {Israeli 1991}, p. 53. [↑](#endnote-ref-47)
47. {Stern 1999a}, p. 443. [↑](#endnote-ref-48)
48. {Strabo, Geographica} 16.2.25. [↑](#endnote-ref-49)
49. {Stern 2004}, pp. 82–83. [↑](#endnote-ref-50)
50. {Baldoni 1987}; {Stern and Schlick-Nolte 1994}, pp. 24–25. [↑](#endnote-ref-51)
51. {Stern 1999a}, pp. 446–447. [↑](#endnote-ref-52)
52. {Strabo, Geographica} 16.2.25. For a detailed commentary on the passage, see Stern 2007, pp. 362–363. [↑](#endnote-ref-53)
53. {Barag 1985}, pp. 113–116. [↑](#endnote-ref-54)
54. {Stern 1999a}, pp. 460–466. [↑](#endnote-ref-55)
55. {Fleming 1999}, p. 42. For a general overview of finds from different areas, as well as of specific techniques and products, see {Fontaine-Hodiamont, Bourguignon and Laevers 2010}. A concise overview of what is known about this technique can be found in {Stern 2010}. For an example of finds from a large Mediterranean city, see {Antonaras 2010c}. [↑](#endnote-ref-56)
56. {Stern 1995}, pp. 46–47. [↑](#endnote-ref-57)
57. {Pliny, *Natural History*} 36.193. For a detailed commentary on this passage, see {Stern 2007}, pp. 359–362. [↑](#endnote-ref-58)
58. {Isings 1957}, p. 45, type 31. [↑](#endnote-ref-59)
59. {Stern 2001}, p. 41. [↑](#endnote-ref-60)
60. {Stern 1995}, pp. 201–246. On the production of mold-blown and dip mold–blown vessels in a large Mediterranean center like Thessaloniki throughout the Roman period and on the relation and juxtaposition of this technique with free blowing, see {Antonaras 2010c}, p. 252**.** [↑](#endnote-ref-61)
61. {Barag 1970c}, pp. 35–63; {Barag 1971}, pp. 45–63; {Stern 1995}, pp. 247–269; {Newby 2008}, passim and see pp. 12–17 for an introduction. [↑](#endnote-ref-62)
62. {Price and Cottam 1998}, p. 13; {Stern 2001}, pp. 27, 133–134. [↑](#endnote-ref-63)
63. {Sorokina 1978}, pp. 118–119, pl. 4.2; this technique has been traced in a workshop of the second and/or third century at Tanais, on the Black Sea. [↑](#endnote-ref-64)
64. {Ignatiadou 2004}, p. 61 [Please add to reference list.]. [↑](#endnote-ref-65)
65. {Martial, Epigr.} 11.11 and 12.74. {Clement of Alexandria, Paedagogus} 2.3.35. For detailed commentary on the passages, see {Trowbridge 1930}, pp. 109, 166, respectively. [↑](#endnote-ref-66)
66. This technique has been studied in detail in {Paolucci 1997}, pp. 17–20 and passim. On techniques that survived through the Middle Ages and in more recent times, see {Charleston 1964}, pp. 83–100 and {Charleston 1965}, pp. 41–54. [↑](#endnote-ref-67)
67. {Paolucci 1997}, pp. 63–80. [↑](#endnote-ref-68)
68. {Lierke 1999}, pp. 67–96, esp. 83–85. On older hypotheses regarding the way of production, see {**Gudenrath and Whitehouse 1990}; {Painter and Whitehouse 1990a}; {Painter and Whitehouse 1990b}; {**Sternini 1995}, pp. 120–121. [↑](#endnote-ref-69)
69. {Whitehouse 1991}. [↑](#endnote-ref-70)
70. {Whitehouse 1990}. For an overview on the matter with many examples from the Corning Museum of Glass collection see {Whitehouse 1997}, pp. 41–65. [↑](#endnote-ref-71)
71. {Stern 2001}, pp. 81–82. [↑](#endnote-ref-72)
72. {Stern 1999b}, pp. 40–41; {Ignatiadou et al. 2005}. [↑](#endnote-ref-73)
73. The term is used for the first time in {Athenaeus, Deipnosophistae} 5.199f, in relation to glass vessels. For a commentary on the passage, see {Trowbridge 1930}, p. 110, 154, note 23. For gilded vessels of this period see {Stern and Schlick-Nolte 1994}, pp. 262–267, nos. 69–70; {Ignatiadou 2000}, pp. 35–36, figs. 1–4; {Arveiller-Dulong and Nenna 2000}, pp. 168–171. [↑](#endnote-ref-74)
74. {Cameron 1996}. [↑](#endnote-ref-75)
75. {Stern 2001}, pp. 139–140. [↑](#endnote-ref-76)
76. {Antonaras 2008}, pp. 298–302. [↑](#endnote-ref-77)
77. E.g. fourth-century vessel from Thessaloniki, (acc. no. ΒΚ 4467/186 in Museum of Byzantine Culture, Thessaloniki) rendering in clay a glass vessel of Isings’s form 103 with indentations around the body. [↑](#endnote-ref-78)
78. {Isings 1957}, p. 46, form 32 and p. 49, form 35. [↑](#endnote-ref-79)
79. {Price and Cottam 1998}, p. 33; {Stern 2001}, pp. 209–211, 242–243, nos. 99–101, 128–129. [↑](#endnote-ref-80)
80. {Stern 2001}, p. 248, no. 134, where there is also a relevant bibliography. [↑](#endnote-ref-81)
81. {Price and Cottam 1998}, pp. 32–33; Stern 2001, pp. 249–251, nos. 135–137. [↑](#endnote-ref-82)
82. {Dussart 1998}, p. 128, BX 111a, table 32/1, p. 158, BX 83, table 46/21, p. 161, BXII.1, table 49/1; {Stern 2001}, p. 354, no. 201; {Gorin-Rosen 2006}, p. 111, note 7. [↑](#endnote-ref-83)
83. {Weinberg and McLellan 1992}, p. 132, no. 107; {Fremersdorf and Polónyi-Fremersdorf 1984}, p. 65, nos. 152–153. [↑](#endnote-ref-84)
84. {Dussart 1998}, p. 162, BXII 214, table 49/7. [↑](#endnote-ref-85)
85. {Weinberg 1988}, pp. 3, 80–81, cat. nos. 351–353, drawing in table 4-39, photo in table 4-15/351, 352, where there is also an older bibliography, as well as technical and production details. [↑](#endnote-ref-86)
86. For typical examples from various periods and places of origin, see {Stern and Schlick-Nolte 1994}, pp. 137, 205, 237, 279, nos. 8, 43, 59, 76; {Stern 2001}, pp. 70, 119, 193, 235, 238, nos. 13, 49, 84, 121, 124. [↑](#endnote-ref-87)
87. {Stern and Schlick-Nolte 1994}, pp. 262–267, nos. 69–70; {Ignatiadou 2000}, pp. 35–36, figs. 1–4; {Arveiller-Dulong and Nenna 2000}, pp. 168–171. [↑](#endnote-ref-88)
88. {Rütti 1991b}. [↑](#endnote-ref-89)
89. {Rütti 1991b}, pp. 134–135. [↑](#endnote-ref-90)
90. {Whitehouse 2001a}, pp. 254, 273–274, no. 866. [↑](#endnote-ref-91)
91. {Vessberg 1952}, type I lid, pp. 149–150, table X, no. 5; {Whitehouse 2001a}, p. 264, no. 859. [↑](#endnote-ref-92)
92. {Whitehouse 2001a}, pp. 253–277. [↑](#endnote-ref-93)
93. {Grabar 1971}, pp. 90–106; {Whitehouse 1998b}, pp. 4–7; {Antonaras 2010b}, pp. 395–397. [↑](#endnote-ref-94)