Original Paper

Recent investigations of early Roman cameo glass

Part 1. Cameo manufacturing technique and rotary scratches of ancient glass vessels[1)]

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The manufacturing traces of ancient cameo glass were investigated. These investigations had a surprising result: early Roman cameo glass vessels have not been cut from overlay blanks. Instead, their manufacture appears to be related to the molding of multi-layered cameo glass gems and to the contemporary relief ceramics. The basic principle of the assumed cameo glass manufacturing process has been experimentally verified. Independently, the typical rotary "scratches" of ancient glass vessels were investigated. Rotary scratches are also a typical feature of early Roman cameo glass. The investigation confirms that these scratches are not grinding marks. They were obviously generated during the hot manufacturing process.

Neuere Untersuchungen über frührömisches Kameoglas
Teil 1. Kameoglasherstellung und umlaufende Kratzer antiker Glasgefäße

Die Herstellungsspuren von antikem Kameoglas wurden untersucht. Diese Untersuchungen hatten ein überraschendes Ergebnis: Frührömische Kameoglasgefäße wurden nicht aus Überfangrohlingen geschnitten. Stattdessen wurden sie wahrscheinlich auf ähnliche Weise in Formen hergestellt wie mehrschichtige Glaskameen und die zeitgleiche Reliefkeramik. Das Grundprinzip der vermuteten Kameoglasherstellung konnte experimentell verifiziert werden. Unabhängig davon wurden die typischen umlaufenden „Kratzer" antiker Glasgefäße untersucht. Umlaufende Kratzer sind auch ein typisches Merkmal frührömischer Kameogläser. Die Untersuchung bestätigte, daß diese Kratzer keine Schleifspuren sind. Sie wurden offenbar während der heißen Glasverarbeitung erzeugt.

1. Introduction

Six years ago, the reticella bowls were presented in this journal as a first example of an ancient glass vessel type which was made hot on a potter's wheel [1]. In the meantime, a systematic search has revealed many other vessel types as possible glass pottery products [2]. A common feature of all examples investigated are rotary scratches on the inside, the outside or on the bottom, sometimes on all surfaces of these vessels (figures 1a and b). Where the ancient surface is sufficiently preserved, these typical scratches appear to be deeply and sharply engraved in a smooth or even shiny context. They are not always exactly parallel. Finally, they do not continue in closed circles or in spirals around the vessel, but they usually have a marked beginning and an end. It was already possible to prove that these scratches were not caused by grinding or polishing as was formerly assumed. Instead they were explained to be an indication of the glass pottery process [4]. This conclusion was supported by several observations, most obviously by some vessels with accidental sickle-shaped folds. In figure 1a such an example is shown again, where the familiar rotary scratches run undisturbed through some folds. In this case the folds are only faint, but still discernible to the eye and to the touch. If the scratches were grinding marks, the folds would have been removed. However, so far the real cause of the rotary marks remained obscur. In section 5 this cause is the subject of an independent investigation. It shall be mentioned in advance that the generation of the scratches could be explained and the previous conclusions were fully confirmed.

Several hundred cameo fragments and about one dozen whole or restored cameo glass vessels [5] from early Roman times are still preserved (figures 2a to d). As a rule, they too feature the typical "scratches" on their inside, or in horizontal segments around their outside, or on the bottom. It is generally assumed that the cameo glass vessels were made by cutting a blown or cast overlay blank [5 and 7]. However, this manufacturing theory has been put forward with caution[2)]. According-

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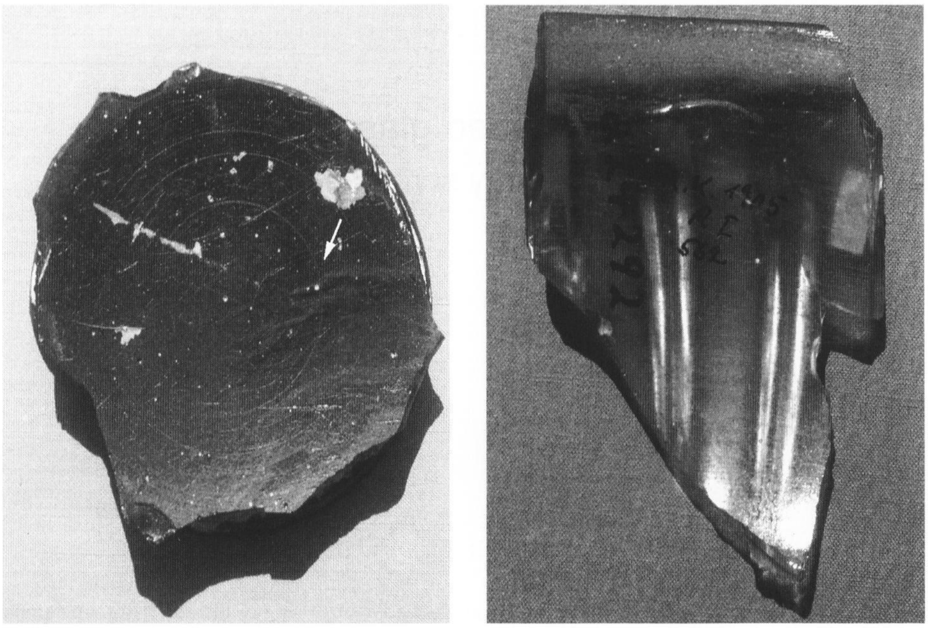
[1)] Extended version of a paper presented at: 13th Congress of the Association Internationale pour l'Histoire du Verre (AIHV) on August 28, 1995 in Amsterdam (The Netherlands) and at: Annual Meeting of Technical Committee V of the German Society of Glass Technology (DGG) on September 23, 1995 in Neuhaus (Germany).

[2)] For a critical assessment of the cutting theory see [8 and 9].



a) b)

Figures 1a and b. Two fragments with rotary scratches; a) dark blue bottom fragment with footring, inside. The surface shows deterioration pits (not to be confused with cut open bubbles) and faint sickle-shaped folds (arrow). Provenience unknown. Kunstmuseum Düsseldorf (Germany). Invt. no. 1990-412. Diameter 7.1 cm; b) rim fragment of a ribbed bowl with fairly well-preserved surface, inside. Museum für Vor- und Frühgeschichte, Frankfurt/M. (Germany). Invt. no. 24292. Height 7.2 cm [3].

a) b) c) d)

Figures 2a to d. Four examples of early Roman cameo vessels; a) the Blue Vase. Museo Archaeologico Nazionale, Naples (Italy). Invt. no. 13521. Height 31.7 cm (after [6, no. 33]); b) the Portland Vase. British Museum, London (UK). Invt. no. GR1945.9-27.1. Height 24.8 cm (after [6, no. 29]); c) small bottle from the Ortiz collection. Height 14 cm (after [5, plate VI]); d) the Auldjo Jug. British Museum, London (UK). Invt. no. GR 1840.12-15.41 and 1859.2-16.1. Height 22.8 cm (after [6, no. 34]).

ing to Whitehouse, the making of cameo glasses is "a thorny problem" [5, p. 26]. Blowing the blank of the Portland Vase for instance (figure 2b) would have been a "tour de force" and the blown blank itself would have been "unusually large for an early blown vessel" [10, p. 124 and 129]. With common acceptance, the Portland Vase is dated soon after 30 B.C. [11, p. 51]. Some cameo bowls or skyphoi (footed two-handled bowls) are dated even earlier. It is assumed that they were made by casting, but how a cast vessel was made with overlay remained a problem [5, p. 27].

These introductory remarks already suggest that also for the cameo vessels, including the famous Portland Vase, the rotary "scratches" may indicate the production on a turning wheel. If one sticks to the common idea that the cameo decor is cut, an overlay vessel blank was needed for the cutting, and this blank could have been made on a turning wheel repectively by a rotary pressing or molding process. A turning wheel production of the blank would help to explain the puzzling problem of how a large overlay glass could be made in a time when otherwise only the first small and thin-walled vessels were blown. It would also easily solve the question of how the overlay blanks for the early cameo skyphoi could have been made. However, the present investigations led to the conclusion that not just the cutting blanks but the complete cameo vessels with their cameo decor already in place were made on a turning wheel. Additional investigations after the first publications [8 and 9] have strengthened this astonishing result. For quicker reference, the most decisive features of the earlier investigations are repeated here, with the addition of the latest observations.

2. Manufacturing traces of early Roman cameo glass

Rotary scratches are usually not known from blown glass. The Auldjo Jug in the British Museum (figures 2d and 3) features these scratches most noticeably around its neck, around the lower part of its body, and on its remarkable bottom with footring (figure 4). If an overlay blank had been made for this vessel, there would have been two possibilities for making the footring. It could have been applied on top of the white layer, or it could have been cut through, respectively, under the white

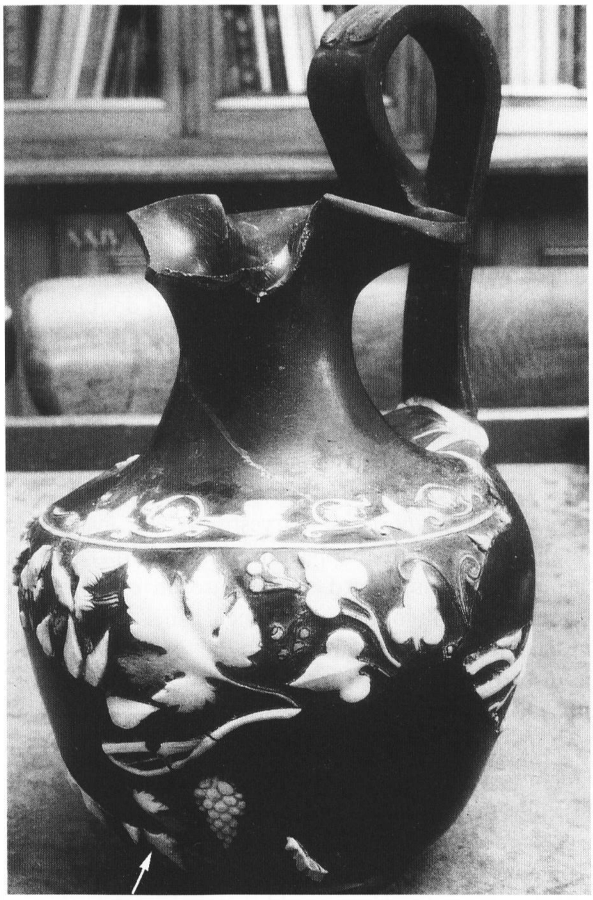


Figure 3. Auldjo Jug (see figure 2d). The unique handle was cut from a longer neck while this was still hot and then applied to the shoulder with a blob of molten glass. The area of this attachment and the white ring around the shoulder are distorted. The arrow points to the detail of figure 5.

Figure 4. Bottom of the Auldjo Jug with rotary scratches (hardly visible). The profile of the moldings and the central dot are identical to the reverse side of the fragment of figure 1a.

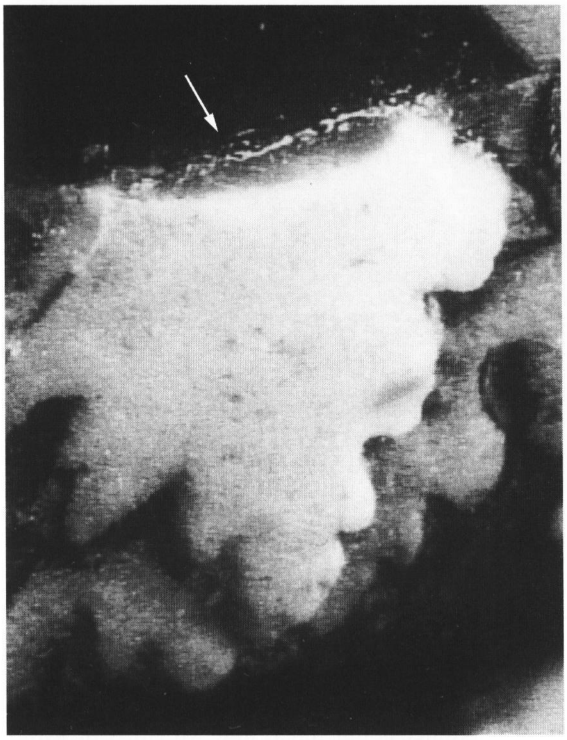


Figure 5. Detail of the Auldjo Jug (compare arrow in figure 3) showing the blue glass protruding into the white cameo layer.

layer from the dark body glass, which of course in this case had to be very thick. Both possibilities can be ruled out. There is no continuous white band between body and footring, which in the first case should have remained from the white overlay. There are, however, some residues of the white cameo decor in the transition area between footring and body to preclude the second possibility, too. Just this one feature should therefore be a sufficient proof that the Auldjo Jug was not made from an overlay blank. A similar conclusion is suggested for other examples, especially for the Blue Vase from Naples (figure 2a) with its pointed foot. There are more features in support of this conclusion.

If a cameo glass was cut from an overlay blank, there should always be an even interface between the two glass layers. However, this is not always the case. The already-mentioned Auldjo Jug shows, at least in one spot, the dark-colored glass of the vessel body bulging into the white cameo decor (figure 5). The same feature is mentioned by Jucker [12] for a fragment in Toledo. Another fragment in the British Museum features a cameo garland on the bottom of an angular recess in the body glass [11, table 19, upper left corner]. Whereever a cameo decor appears to be partly rubbed off, the body glass usually remains somewhat raised and pitted. Most often, these bared parts still show a rounded relief in the dark body glass (figure 6, compare also some tendrils in figure 3). There is no way to explain these features if an overlay blank had been cut.

As a rule, any modern cut overlay glass still permits to discern respectively to restore the concept or the original outline of the cutting blank which was used. This rarely applies to early Roman cameo glass. Its ca-

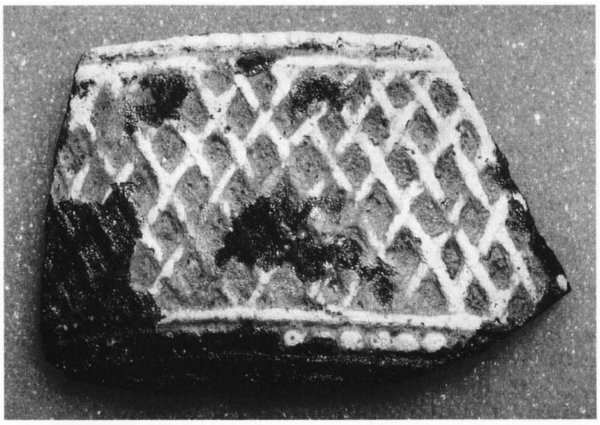


Figure 6. Cameo vessel fragment. The blue glass shows a rounded relief under the white glass layer, precluding that the cameo decor was cut from an overlay blank. Previously unpublished. Römisch-Germanisches Museum, Köln (Germany). Invt. no. N 6408a. Height 3.1 cm, width 4.9 cm, thickness ≈3 mm. (This fragment seems stylistically related to Hellenistic pottery [13].)

meo decor is everywhere well-rounded, sometimes with almost three-dimensional relief, and with tips of leaves pointed freely out of the surface (e.g. figure 2a). Nothing is preserved of the assumed original surface of a cutting blank, and hardly any traces are left which could be interpreted to be grinding or cutting marks. This is strikingly different for late Roman cameo glass, for instance the Hunting Bowl from Stein am Rhein, which is definitely wheel-cut [9, figure 16; 14, figure 41]. On this vessel, the traces of wheel-cutting can clearly be discerned, especially all over the background. The cutting is edgy and rough, and the original top surface is still preserved in wide areas as part of the design. Matcham and Dreiser [15] wrote about relief cut glass, "No matter how well the background is removed and smoothed out, the marks of the tool can be detected on the polished surface". This statement is confirmed by any modern wheel-cut replica of ancient glass, where cutting marks clearly can be discerned all over the surface. By comparing early Roman with late Roman cameo glass, or with wheel-cut modern replicas, one has to conclude that a significantly different manufacturing technique was employed.

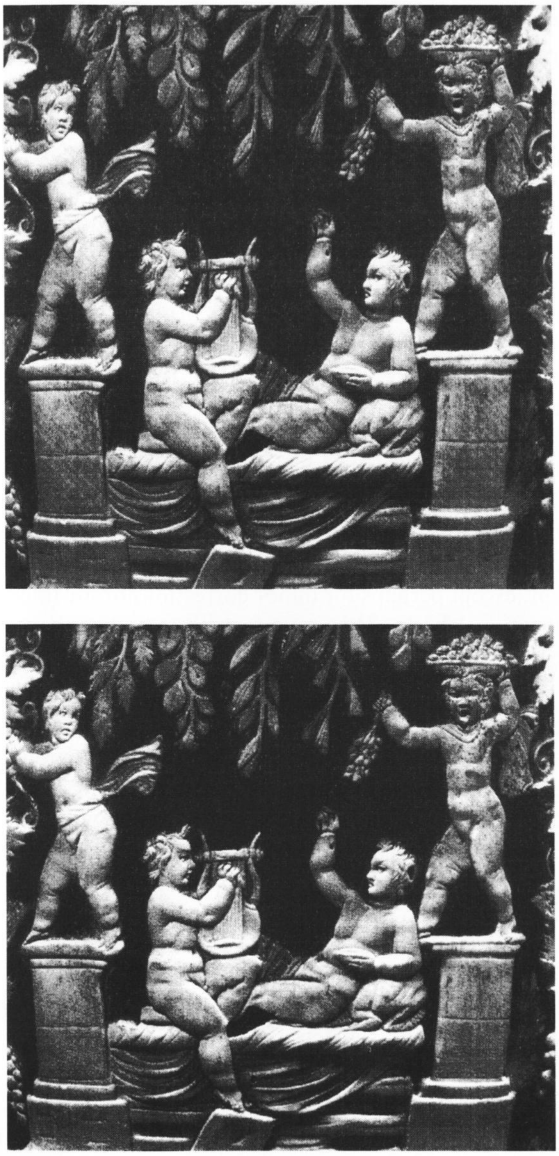
One of the most telling features of early Roman cameo glass is the manner in which the handles are applied. In all known examples they are fused with a blob of glass to the already finished cameo design (e.g. figures 2a, b, d), [8, figures 32b, 33, 34, 36, 39a]. Unworked glass under the handles was already noticed at the Portland Vase by Simon [11, p. 3]. Since it is not possible that a vessel body with a laboriously cut cameo design was reheated to apply a handle after the cutting, the cameo decor must have been finished in one hot process together with the vessel body. This becomes most obvious again for the Auldjo Jug, where the handle was not applied separately, but was cut from an originally much longer neck while the glass was still hot [8, figure 39a; 16]. The end of this still pliable handle was then applied to the body on top of the cameo decor with a blob of molten glass.

The body of the Auldjo Jug became distorted at the lower attachment point of the handle (figures 2d and 3). Because of the fragmentary condition of this jug, it is not easy to tell whether the cameo decor became distorted here, too. However, a hot distortion is shown clearly by the white cameo ring around the shoulder of the Auldjo Jug (see figure 3). There is no doubt that a cut cameo ring would be strictly horizontal. Stretched figures and oblong open bubbles seem to be proof of a hot distortion of the Blue Vase from Naples (figures 2a and 7a). It obviously looks as if the figural scenes, which are situated below the handles, were stretched while the glass was still viscous. By vertically compressing a computer image of the grape harvesting scene, everything obtains a more normal appearance (figure 7b). The putti become as squareheaded as they are on other cameo glasses, especially on the two cameo panels in the same museum [6, no 32; 8, figures 9a and b]. Naturally, a plastic distortion of a cut cameo decor would not be possible.

All early Roman cameo objects – vessels, plates or panels – are so closely related in their appearance that basically the same manufacturing technique must have been used. A fragment in the New York Metropolitan Museum [17] originally belonged to a platter of more than 1 m diameter. How would it have been possible to cut such a huge object? No cutting faults could be detected in cameo glasses. Slipped or stuttered lines for instance, which are so frequent in contemporary and later Roman intaglio engravings, are conspicuously absent in cameo glass. There are other faults, however, even on the Portland Vase. The lady sitting on a rock (reverse side of figure 2b) has an ugly deformed foot (figure 8), which was partly squeezed flat, presumably while it was in a plastic state. This deformation easily could have been "healed" by cutting, but obviously, no cutting was applied. There is only one conclusion possible: early Roman cameo glass has not been finished by cutting an overlay blank. It was made by molding.

3. Early Roman cameo glass and its technological context

The inspiration for cameo glass vessels may have come from cameo stone vessels, just as glass cameos imitate cameo gemstones. The precious cameo gemstones have been known since the 3rd century B.C. Gemstones with intaglio engraving were copied very early in glass by pressing hot glass into a mold which was taken by casting from the archetype. The same must have been tried for cameo gems. It was shown by Weiß [19] that powdered glass was used in the making of multilayered glass cameos. This confirms the experience of the author. With glass powder, it is possible to reproduce the finest details in glass (figure 9). The glass powder is molten in a negative mold which is taken as cast from the arche-



a)

b)

Figures 7a and b. Harvesting scene of the Blue Vase ([6, no. 33, p. 76]; see figure 2a). a) It looks like a deformation during the hot manufacturing process caused oblong bubbles and stretched figures, b) computer image of the same scene ≈10% vertically compressed (P. Huber, tec5 GmbH, Steinbach).

Figure 8. Detail of the Portland Vase (see figure 2b). Foot with modelling flaw, not corrected by cutting [18].

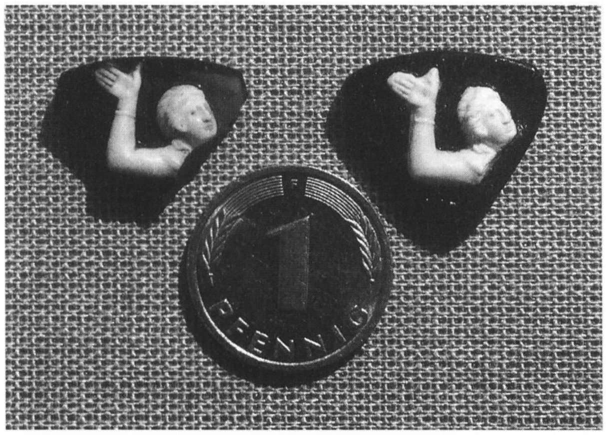


Figure 9. Agate cameo fragment (left) and a glass copy thereof, made by the author with powdered glass. Glasmuseum Wertheim (Germany). Invt. no. NH 3136 (without provenience).

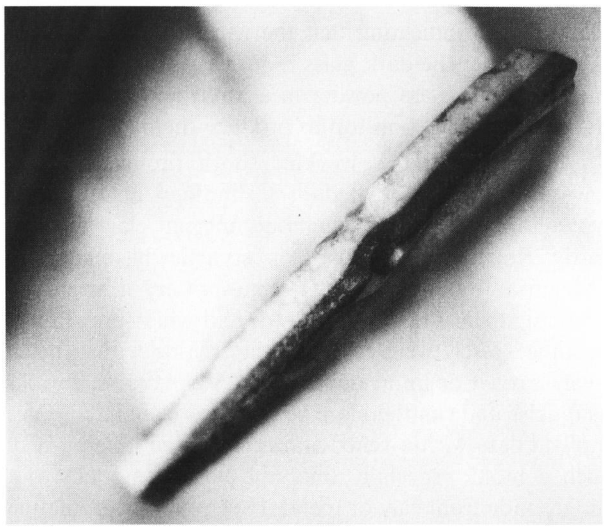
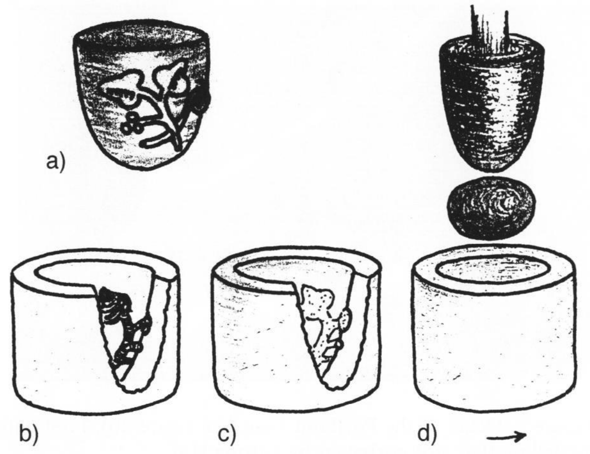


Figure 10. Fragment of a cameo plate. An air bubble was trapped between the white cameo layer (below) and the dark body glass. The dark glass was raised, indicating that the cameo layer was under the dark glass while it was hot. The fragment is backed by a second white layer. British Museum, London (UK). Invt. no. GR 1886.11-17.3. Width ≈5 cm.

type. If one presses a bit of molten glass into the mold instead of melting glass powder, air can be trapped in the deeper cavities of the mold, thus blurring the design [8, p. 194]. This fault is avoided by the use of powder.

It is only a small step from melting glass cameo gems in molds to melting cameo plates in the same way. It has been mentioned that cameo plates of more than 1 m diameter were made in antiquity. Only after the invention of the flexible shaft in this century could plates of this size be cut and engraved without great difficulties. It therefore seems certain that ancient cameo plates were made by molding. An extra proof is given by a fragment of a plate in the British Museum, where an air bubble was trapped under the dark background (figure 10). This bubble raised the background layer (backed by another



Figures 11a to d. Making of a cameo bowl; a) model, b) mold, c) mold cavities filled with glass powder (cameo enamel), d) hot glass pressed into the rotating mold to make the vessel body.

Figure 12. Three experimental cameo bowls. The cameo decor has not been cut. Diameter of bowl approximately 8 cm.

white layer), indicating that the white cameo layer was molten under the dark glass – just as would happen by melting white glass powder in a mold and pressing the dark-colored glass on top to produce the background.

Pottery and glass working, both fire-using crafts, have been closely related in technology and in their workshop locations throughout ancient glass history. Early Roman cameo glass is stylistically related to "Megarian" bowls and Arretine pottery respectively Terra sigillata. These well-known and wide-spread relief ceramic vessels were made in clay molds with a negatively carved or impressed design. A clay vessel shrinks as it dries and can therefore be removed from its reusable mold. Glass with a relief cannot easily be taken out of such a mold, especially since the hot glass sticks to a mold made from clay or metal. However, a combination of the familiar manufacturing process of relief ceramics together with the experience gained in the making of glass cameos and cameo plates (e.g. the use of glass powder and plaster molds) leads straight to the most likely manufacturing method of early Roman cameo glass vessels.

4. Cameo glass vessels – made hot on a potter's wheel

It is easy to transfer the method of molding cameo glass plates to molding flat cameo dishes. The making of a cameo bowl is also not difficult. Four steps are necessary (figures 11a to d): a) a wax or clay model is made, b) a plaster mold is taken from the model, c) the negative design in the mold is filled with a white glass powder slurry, d) glowing hot dark glass for the vessel body is filled into the mold and pressed firmly with a plunger while the mold rotates on a wheel. The rotation ensures a very fast and even distribution of the hot glass, which melts the white glass powder in the mold cavities with its glowing heat. Glass does not stick to plaster if certain limits concerning temperature and humidity are observed, and therefore, the mold can quickly and easily be broken off from the finished glass bowl. Model and mold are lost; every piece is unique. Nothing has to be cut, except perhaps for minor corrections or for finishing the vessel body. This manufacturing method has been experimentally verified (figure 12).

The cameo molding process can be compared with enameling. The most decisive difference is the heat source for melting the glass powder. Ordinary glass enamel is a powdered glass with a low melting temperature. For glass enameling, a glass vessel with applied enamel powder is cautiously heated to moderate temperatures until the enamel melts, but the vessel is not softened. For a cameo vessel, the white glass powder or "cameo enamel" is kept in the cavities of the mold and fused by the direct impact of the much higher heat of the glowing hot body glass. Simply stated: for a cameo vessel a three-dimensional enamel decor is made first and the vessel "filled in" later.

Naturally, it would be helpful if the cameo enamel, just like ordinary glass enamel, would be a low-melting glass. Analyses have shown [20] that this is the case. There is a substantial amount of lead in the white glass of cameo vessels, while there is less or none in the dark glass of the vessel body, except for flat plates or dishes, where usually little or no lead was detected, either in the white or in the dark glass. This relationship has been confirmed for the author by analyses of 14 cameo glass fragments from the Römisch-Germanische Museum, Köln (Germany). The new analyses and the method used to obtain them will be presented in the second part of this paper [21]. Lead lowers the melting temperature of glass and this must have been the reason for adding it to the white cameo enamel of the cameo vessels. Flat cameo plates or dishes could easily be pre-fused if desired, and therefore a lead addition was not really necessary[3)].

For a thicker cameo layer with undercut parts, the cameo enamel can be sintered before the hot body glass is pressed into the mold.

[3)] In the experiments, a lead addition proved to be favorable, but not in all cases essential.

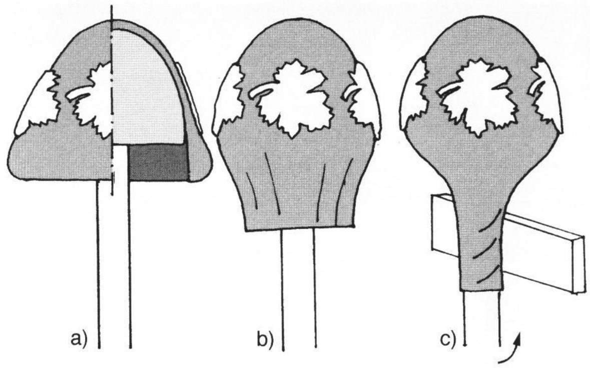
So far, only the making of a bowl has been described. For a vase or bottle shape, two additional steps are required. The ancient originals (e.g. figures 2a to d) have no cameo decor at the neck, and therefore, the following procedure seems to have been used (figures 13a to c): a) a cameo bowl is made first with a broad and thick undecorated rim. This bowl with its still glowing hot bulging rim is immediately placed upside down onto a plaster core on a rod. The core may be identical to or similar to the plunger used for pressing. b) The glowing hot rim will flow and stretch naturally and c) can be tooled if desired. Handles or a foot could be added and manipulated. The handle, for instance, may be cut from a surplus length of the neck as is shown by the unique handle of the Auldjo Jug (figure 3). Flowing striations on the inside of the neck of the Auldjo Jug [8, figure 31] further support the proposed method. The feasibility of this method was verified. A simple glass vessel was made by sagging a glass gather over a core without any additional manipulations [8, figure 4; 9, figure 2]. The figural scenes of the Blue Vase (figures 7a and b) probably became distorted by the weight of the handles during such an upside-down sagging process. The same applies to the Auldjo Jug, where the weight of the handle obviously pulled the body out of shape (see figures 2d and 3). One has to conclude the same possibility again for the Portland Vase from its description [7, p. 114].

Cameo glasses may or may not have been treated by a short firepolish after the plaster mold was taken off. A plaster mold becomes brittle through contact with the hot glass. It could not be used a second time even if it had survived the molding. Cameo glasses therefore have always been unique works of art, no matter whether they are molded or cut.

5. Investigation of the rotary scratches of ancient glass

The appearance of rotary marks on ancient glass vessels was studied on detailed photographs of about 20 different glass vessels, including 6 cameo vessels respectively fragments. Two fragments of early Roman vessels were analyzed in the laboratory to receive more information about the cause of these marks (figures 1a and b). The surface was investigated by microscopy illuminated from underneath and from above, magnified 10, 25 and 50 times. One fragment belonged to a blue vessel, presumably from the bottom part; the second was a rim fragment, belonging to a transparent light green vessel with ribs. Both fragments featured the typical rotary marks on the inner surface. The blue glass unfortunately had severe traces of natural leaching (surface pitting), it therefore was omitted from further considerations. The light green glass did not suffer from comparable environmental attack.

On the inner surface near the rim, traces from cold abrasion were detected (figure 14a, top). Below that part of the fragment, the inner surface was shiny except for the horizontal marks. These marks were limited in length. Magnified 25 times they looked like scratches



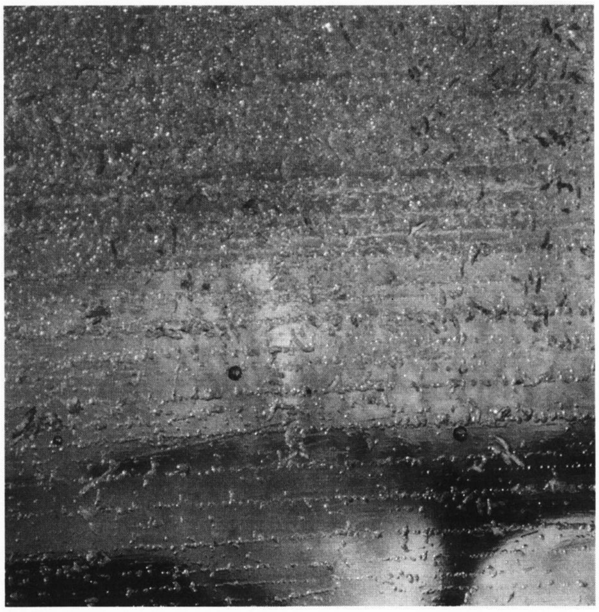
Figures 13a to c. Making of a cameo bottle; a) a cameo bowl with still glowing hot thick rim is placed onto a plaster core on a metal rod; b) the glass flows further down by its own weight, the surface tension of the hot glass will cause a slight constriction below the core; c) the neck may be tooled.

(figure 14b). The surface in general looked shiny but not totally even. Typical are the horseshoe marks of the scratches. They indicate the direction of the force which caused the scratches. There were few exceptions to the prevailing direction. The individual horseshoe marks did not show a sharp contour. They looked smoothed. Some scratches were of a smaller size.

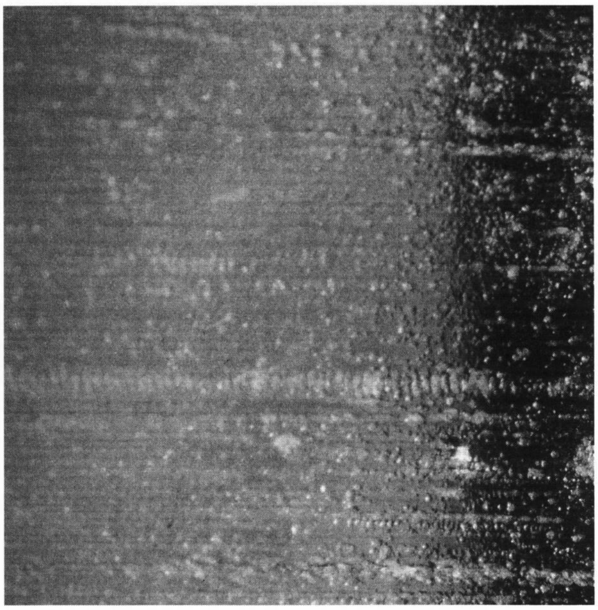
From this description of the surface in the lower part of the fragments, any supposed cold finishing work can be excluded. The surface condition is untypical of a ground surface. It is comparable with a glass surface obtained by a casting process. More typical of grinding and helpful in the determination is the glass part close to the rim. Here the character of the cast glass is not visible anymore. Surface treatment, perhaps from usage, has changed the appearance. The surface is evenly covered with marks.

It is conceivable to explain some of the scratches in the lower part by handling and all kinds of treatment during the centuries. This may be especially true for the tiny scratches. However, the individual shape of the horseshoe marks indicates a different explanation for most of the scratches, which is in good accordance with the favored theory of the manufacturing on a turning wheel. If the glass was spread over a rotating mold, it must have performed a short motion relative to the mold. Small pits elevated on the surface of the mold could have injured the glass surface. The heat capacity of the glass itself caused a reheating of the scratches. The scratches thus were partially cured and the marks got a smoother contour.

A generation of scratches is reasonable from a theoretical standpoint. Moreover, there are examples of similar scratches in the modern glass production (figure 15). During pressing or mold blowing, tiny injuries on the mold surface are causing scratches on the glass surface. Similar to the ancient example the glass in contact with the mold is cooled down on the surface. The motion of the glass along the mold surface causes the so-called

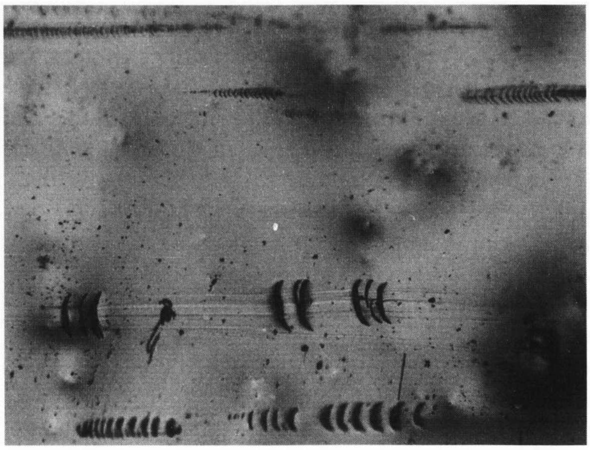


a) 1 mm



b) 1 mm

Figures 14a and b. Details of the fragment from figure 1b, a) showing the rough surface near the rim and the shiny surface further down with rotary marks, b) showing the scratches with horseshoe markings. (Photo: H. Strothotte, Schott Glaswerke, Mainz (Germany)).



0.5 mm

Figure 15. "Hot scratches" with horseshoe markings in the TV glass production. (Photo: O. Lindig[4], Jenaer Glaswerk Schott & Gen., Mainz, 1976.)

"hot scratches"[4]. If they are not too deep, the reheating of the surface by the internal heat of the glass piece can soften or remelt in some way the marks, so that any further growing of the surface injuries will be prevented. The reheating of this kind of scratches is apparent and comparable with the ancient examples. The assumption that the smoothed contour of the scratches is caused by a change during time is not very plausible because of the good condition of the surface in general.

6 Conclusion

The investigations confirmed that the typical rotary scratches of ancient glass vessels are not grinding or polishing marks. The scratches obviously were created at the very outset of the turning wheel forming process through the sliding of the hot glass against blemishes on a cold surface. This may be the surface of a mold or of a tool. It becomes comprehensible that, as a rule, most vessels of a certain type show these typical marks while some of the same type don't. Perhaps, the quality of the ancient mold or tool material was not reliable. It also becomes comprehensible that the same kind of rotary marks is featured by vessels as different as ribbed bowls and cameo glass. The proposed method of molding the cameo vessels, using a lost plaster mold with glass powder for the cameo decor, and placing the mold on a turning wheel during the vessel production, is in agreement with these manufacturing traces. Molding instead of cutting the cameo glass fits well into the technological context of early Roman fire-using crafts, and into a logical chronological development of ancient glass technology. One no longer needs to assume that only about one generation after the humble beginnings of glass blowing, this new art of glass working was used to produce overlay cutting blanks with up to six layers and remarkable

[4] Original quotation in German in "Projekt 6001 – Sichtfehlerbewertung (Notiz vom 20.4.1976)" by O. Lindig, Jenaer Glaswerk Schott & Gen., Mainz: „Bei diesem Rutschvorgang erzeugen Erhebungen in der Formenoberfläche Gleitspuren im bereits zähplastischen Glas, die – je nach Glastemperatur (Zähigkeit/Sprödigkeit) sowie Größe und Form der Erhebung auf der Formenoberfläche – zum periodischen Aufreißen der Gleitbahn führen können. Die Tiefe solcher Risse ist 1. durch die Verteilung des Kraftfeldes um die die Gleitspur erzeugende Erhebung, 2. durch das zum Inneren hin logarithmisch steigende Fließvermögen des Glases begrenzt. Mechanismus 2 sorgt weiterhin für eine gewisse Ausrundung des Kerbgrundes und damit für eine Verminderung des Kerbfaktors."

size and thicknesss. Instead, it may even be possible to reconsider the dating of some cameo vessels. Some of them may have been erroneously dated late, because it was assumed necessary that they were blown. In any case, the assumption is no longer required that all-time masterworks of glass cutting were made 2000 years ago which for centuries later could not be duplicated by this method despite improved cutting tools. But, whether the early Roman cameo glasses are molded or cut, they remain unique masterworks of art. Their manufacturing process is an impressive example of human ingenuity.

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With kind permission and help by the persons mentioned, the following objexts were investigated: the glass cameo vessel of the Musée des Beaux-Arts et d'Archéologie, Besançon (France), (M. Lagrange); several glass and stone cameos, Rheinisches Landesmuseum, Bonn (A. B. Follmann-Schulz, U. Heimberg); 17 cameo glass fragments and a selection of cameo gemstones, Römisch-Germanisches Museum, Köln (Germany), (F. Naumann-Steckner); two fragments, Kunstmuseum Düsseldorf (Germany), (H. Ricke); several fragments and vessels with rotary scratches. Museum für Vor- und Frühgeschichte, Frankfurt/M. (Germany), (D. Stutzinger, I. Zetsche); the Auldjo Jug and about 30 cameo glass fragments, British Museum, London (UK), (V. Tatton-Brown); a glass cameo, Museum Magdalensberg (Austria), (S. Zabehlicky-Scheffenegger); the Hunting-Bowl, Allerheiligenmuseum Schaffhausen (Switzerland), (G. Seiterle); a cameo fragment, Glasmuseum Wertheim (Germany), (M. Tazlari); 3 cameo glass or relief fragments, an onyx cameo vessel (AS X 22) and several cameo gemstones, Kunsthistorisches Museum, Wien (Austria), (A. Bernhard-Walcher, K. Gschwantler); 3 cameo glass or relief fragments, Martin-v.-Wagner-Museum, Würzburg (Germany), (I. Wehgartner, C. Weiß); the early cameo glass bowl in the Oppenländer Collection (G. Oppenländer). The author expresses her sincere gratitude for the possibility of close-up investigations and for the permission to take and publish photographs (figures 3, 4, 5, 10 by courtesy of the Trustees of the British Museum). More cameo glass vessels, plates and fragments as well as cameo gemstones and vessels have been studied within their case in several museums and exhibitions in Europe and the United States. Dr. F. Naumann-Steckner kindly permitted to publish the fragment of figure 6 for the first time; Prof. E. Simon and Dr. C. Weiß, both Würzburg (Germany), Dr. M. Feldmann, Erlangen (Germany), Dipl.-Ing. B. Fleischmann, Frankfurt/M. (Germany), and many others helped with advice concerning archeological and technological questions. The Römisch-Germanische Kommission, Frankfurt/M. (Germany), provided for the ideal opportunity for literature research and valuable discussions with its staff and visitors.

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7. References

[1] Lierke, R.: Glass bowls made on the potter's wheel. A new approach to ancient glass technology. Glastech. Ber. **64** (1991) no. 12, p. 310–317.
[2] Lierke, R.: Glass vessels made on a turning wheel in Roman times. Survey. In: Annales du 13e congrès de l'Association Internationale pour l'Histoire du Verre (AIHV), Amsterdam 1995. (Publ. 1997.) p. 55–62.
[3] Welker, E.: Die römischen Gläser von Nida-Heddernheim II. Schriften des Frankfurter Museums für Vor- und Frühgeschichte VIII. Bonn: Habelt, 1985. p. 13.
[4] Lierke, R.: It was the turning wheel, and not the lathe. Mold pressing and mold turning of hot glass in ancient glass vessel production. Gastech. Ber. **66** (1993) no. 12, p. 321–329.
[5] Whitehouse, D.: Cameo glass. In: Newby, M.; Painter, K. (eds.): Roman glass. Occasional papers from the Society of Antiquaries of London **12** (1991) p. 19–32.
[6] Harden, D. B.; Hellenkremper, H.; Painter, K. et al.: Glass der Caesaren. Milano: Olivetti, 1988.
[7] Gudenrath, W.; Whitehouse, D.; Recent research on the Portland Vase. Pt. 3. The manufacture of the vase and its ancient repair. J. Glass Stud. **32** (1990) p. 108–121.
[8] Lierke, R.: Die Portlandvase – ein Produkt der Töpferscheibe? Zur Herstellungstechnik der römischen Kameogläser. Antike Welt **27** (1996) no. 3, p. 191–207.
[9] Lierke, R.: Glass vessels made on a turning wheel. Cameo Glass. In: Annales du 13e congrès de l'Association Internationale pour l'Histoire du Verre (AIHV), Amsterdam 1995. (Publ. 1997.) p. 63–76.
[10] Painter, K.; Whitehouse, D.: Recent research on the Portlandvase. Pt. 4. Style, date, and place of manufacture. Pt. 5. The place of the vase in Roman glassmaking. J. Glass Stud. **32** (1990) p. 122–125, 126–129.
[11] Simon, E.: Die Portlandvase. Mainz: Verl. Röm.-German. Zentralmuseum, 1957.
[12] Jucker, H.: 'Promenade archéologique' durch die Ausstellung der Sammlung Kofler im Kunsthaus Zürich. Antike Kunst **8** (1965) p. 40–54, footnote 53.
[13] Rotroff, S. I.: Hellenistic pottery. Athenian and imported bowls. The Athenian Agora. Vol. XXII. Princeton, NJ: The American School of Classic Studies at Athens, 1982. Pl. 69/404, p. 92.
[14] Lierke, R.: Vasa diatreta. T. 1. Ein kritischer Exkurs über die Glasschneidekunst der Römer. Antike Welt **26** (1995) no. 1, p. 42–59, figure 41.
[15] Matcham, J., Dreiser, R.: The techniques of glass engraving. London: Batsford, 1982, p. 96.
[16] Harden, D. B.: New light on the history and technique of the Portland and Auldjo cameo vessels. J. Glass Stud. **25** (1983) p. 45–54.
[17] Goldstein, S. M.; Rakow, L. S.; Rakow, J. K.: Cameo glass. Masterpieces from 2000 years of glassmaking. The Corning Museum of Glass 1982, p. 25 and 102.
[18] Haynes, D. E. L.: The Portland Vase. London: The Trustees of the British Museum, 1964. Detail of table VIII.
[19] Weiß, C.: Nachrichten aus dem Martin-von-Wagner-Museum. Neues aus der Gemmensammlung. Archäologischer Anzeiger (1995) p. 547, note 294.
[20] Bimson, M.; Freestone. I. C.: An analytical study of the relationship between the Portland Vase and other Roman cameo glasses, J. Glass Stud. **25** (1983) p. 55–64.
[21] Mommsen, H.; Brüning, A.; Dittmann, H. et al.: Recent investigations of early Roman cameo glass. Pt. 2. X-ray fluorescence analysis induced by synchrotron radiation (SYXRF). Glastech. Ber. Glass Sci. Technol. **70** (1997). (In prep.)

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