

N.B. This is a very rough, preliminary, draft of the book which was finally published as 'The Glass Bathyscaphe: How Glass Changed the World' by Profile Books, London, 2002. This draft was completed about nine months before the final book. Many arguments are provisional, the footnotes have not been checked, the order is different. But it does contain many bibliographical details and quotations which were excluded from the final published work. It may therefore be useful for those who wish to pursue the matter further or to know the background to certain statements in the published work.

GLASS IN WESTERN EUR-ASIA TO THE FALL OF ROME

No-one is certain as to where, when or how glass originated, but for the purposes of this book this does not matter greatly. The 'where' can broadly be answered by suggesting origins in the Middle East, perhaps in more than one place including Egypt and Mesopotamia. As to when, this varies between some who suggest hints of glazing on pottery as early as 8000 B.C. and more common estimates of the origins of glass at between three and two thousand B.C. As to how, all is complete guesswork and we can only say that it was originally made, or found in natural blocks, by accident.

Matters become clearer if we place ourselves at the point at which the number of recovered glass objects suddenly increases, that is about 1500 B.C., which was also the time when the 'core-formed' technique evolved, mainly used in the manufacturing of glass vessels. At that point glass making extended along much of the eastern end of the Mediterranean and through the Phoenicians was set to spread through the Greek islands and north Africa. In this period glass was used for three purposes, to glaze pottery, to make jewellery and to make small containers mainly for liquids. It was produced by various methods but these did not include glass blowing. From finds made in Turkey and Mesopotamia it is clear that glass-makers were attempting to produce a clear colourless material free of all impurities from at least as early as the eighth century BC. Clear, colourless glass was probably being produced in Persia, Greece and Mesopotamia from the fourth century BC, and Egypt's Alexandria workshops are thought to have made clear, colourless bowls, cast and ground to shape, from the third century BC onwards.¹

Somewhere between 1500 B.C. and the birth of Christ, perhaps around 500 B.C., glass-making techniques spread to East Asia and were known to the Chinese. Thus by about 100 B.C. much of Eur-Asia had a common knowledge base, namely the ability to make coloured and plain glass. The use continued to be mainly for the same purposes, glazing pottery, decoration (jewellery) and containers. It is this common base, spread over all of Eur-Asia, which has been one of the bits of popular knowledge that can easily lead us into believing that there is very little difference in the history of glass over the world. If the Indians, Chinese, Japanese and

¹ Vose, Glass, 21

west Asians all knew about glass over two thousand years ago, how can it have played an important part in differentiating civilizations? The only way to explore this is to look at the period after about 100 B.C.

This date is taken for one major reason. At some point in the century before the birth of Christ, somewhere in Syria or Iraq, a revolutionary new technique of making glass was introduced, vastly extending its possibilities. Up to this point glass was made in blocks and then worked. It was not obvious that it had any potentials in the field of optics. It was just a substance which could mimic others, it was like clay, or could be used to imitate precious stones. As McGrath writes, 'Glass in the ancient world did not connote transparency. Indeed, transparent glass was a rare exception and was apparently **tabu** like crystal. It was usually coloured and opaque and therefore exploited in quite a different way...' ²

Then came the invention of glass-blowing. We tend to think of this again as an obvious development, but the fact that it probably took up to five hundred years for this technique to spread from its source to China shows that it was far from easy, even when invented. As McGrath again explains, 'Whatever its date it was certainly a remarkably ingenious invention. To manipulate molten glass in this fashion is by no means so obvious as its effectiveness leads one to think, and necessitates in any case that additional 500 deg. C. or so of temperature to get the metal into a sufficiently liquid form which the ancients found quite impossible to achieve. The long racial experience with furnaces of the Syrians no doubt expedited the achievement in their case.' ³

After glass blowing one could make thin glass and the whole development of its new uses began. It is really just over two thousand years ago that the great divergence in its use began. In order to trace their causes and consequences we have to examine the various civilizations separately. I shall do so in relation to five major uses of glass. The first three are usefully distinguished using the more specific French terms for forms of glass. Instead of the collective English noun 'glass', in French one has 'verroterie', that is glass beads, counters, toys and jewellery. Then there is 'verrerie', that is glass vessels, vases and other useful ware. Thirdly there is 'vitrail' or 'vitrage', that is window glass. To this we may add two more. There are mirrors, and there are lenses and prisms, including such applications as spectacles.

* * *

It is arguable that it was the nature of glass manufacture in Roman civilization which is one of the two or three most important causes of what we shall try to establish, namely the development of the peculiar place of glass in western civilization. What we are dealing with is in fact divided into two parts; a technical and attitudinal revolution, connected yet separable. The technical revolution provided a technology which was in many ways unrivalled until the nineteenth century. The attitudinal revolution, in which glass was seen as a highly important material in its own right, is really what distinguishes the history of glass in western Europe from its non-history in Asia. It is thus very important to devote some attention to the platform upon which later developments would be built.

²McGrath, Glass in Arch., 27

³McGrath, Glass in Arch., 29

In the five hundred years from 100 B.C., which coincides with the great period of Roman civilization, the history of glass was transformed by two events. The first, as we have seen, was the discovery of the art of glass blowing, probably in Syria, in the century before Christ's birth. This technique spread incredibly quickly over the next fifty years over most of the Mediterranean by way of the Roman Empire, and was later adopted in China. This new technique enormously increased the versatility of glass and, in particular, opened up potential new uses, for decorative drinking vessels and flat panes of glass for windows.

This revolutionary change coincided with the peak of Roman civilization, which placed glass at the centre of its interior decorative development. As many have pointed out, glass came to be used in Italy for a diversity of utensils and other decorative uses which has never been equalled since then. The techniques and quality of the glass objects were unrivalled in the world until the nineteenth century. All that was needed to make use of glass, as well as an enormously high valuation of its potential, were thus present in western Europe by the start of the Christian era.⁴

The technological and the ideological changes came together, for after the development of glass-blowing it 'was now possible to produce glass vessels quickly, cheaply and in large quantities and a wide variety of forms. Glass also had the advantage of being impermeable, easily cleaned and reusable, and, for the first time, it was treated as a substance in its own right...'⁵ It was such a versatile, clean and beautiful substance: 'all at once here was a material that was clear, malleable when hot but rigid when cold, easy to clean (the Romans were obsessed with cleanliness compared to previous civilizations, and their real love of glass may have been spurred on by the fact that it could be hygienically cleaned in a way impossible for wood or earthenware), able to keep out the weather and let in the light.'⁶ Its high rating meant that 'Glass, like silver, gold and other materials, began to be used to promote the cult and image of the emperor throughout the Roman Empire and beyond its frontiers.'⁷ Indeed, it may have been its success which undermined ceramics, rather than the defects of ceramics which led to the need for glass. 'In fact, the new popularity of glass among all levels of society brought it into direct competition with the ceramics industry, even resulting in the demise of Italian thin-walled pottery.'⁸ This throws a new complexion on what happened in Asia. There the much older and more sophisticated pottery tradition, plus the national hot drink (tea), kept glass out, but in Roman civilization for the first time people opted for glass drinking vessels. This is a crucial step to which we shall return.

Another development, with great implications for the future, was the realization that clear glass was both useful and beautiful. In all civilizations up to Rome, and in all other civilizations

⁴ For a brief overview, see **Late Antiquity** eds. G.W.Bowerstock et al. (Harvard, 1999), 470

⁵ Sotheby, glass, 30

⁶ Encyclopedia of Glass, 33

⁷ Sotheby, glass, 27

⁸ Sotheby, glass, 30

outside western Eur-Asia, glass was chiefly valued in its coloured form, particularly as an imitation of precious stones. The consequences of this were not, of course, known at the time, but we shall later see that the development of glass as a thinking tool, through mirrors, lenses, spectacles, is absolutely dependent on the making of fine clear glass. The Romans could make beautiful coloured glass. 'The Romans had at their command, of transparent colours, blue, green, purple or amethystine, amber, brown and rose; of opaque colours, white, black, red, blue, yellow, green and orange.'⁹ Yet, very early on, the most prized glass came to be colourless. 'Pliny (c.30 A.d.)...tells us that "the most highly valued glass is colourless and transparent, as closely as possible resembling rock crystal". Possibly glass was becoming more acceptable as a material in its own right, and glass-workers were no longer attempting to imitate the products of other industries to the same extent.'¹⁰

The development of colourless glass is well described by Tait. 'From about AD 70 much of the finest glassware was made of intentionally decolorised glass. This colourless glass came to replace not the natural shades with a greenish or bluish tinge, but those deliberately coloured such as blue, purple and amber. Among the earliest, if not the first, completely transparent blown glass vessels of the Roman era are pieces decorated with facet-cut designs, made between about AD 70 and 117...'¹¹ Then we are told that 'Until the fourth century, intentionally coloured glass became very rare for vessels....the finest or most luxurious pieces were now for the most part made of colourless material, while natural greenish and bluish-greenish glass was employed for some decorated vessels but in particular for utilitarian ware, which was produced in profusion.'¹² Thus 'Ordinary everyday domestic table and storage wares were for the most part made in plain, undecorated glass, and wide range of shapes was produced...'¹³ Reading this, we need to remind ourselves how strange this was; almost everywhere the wonderful ability of glass to take colour had been one of its greatest assets. The Romans let their glass play with light in a subtler way, perhaps aided by their predilection for wine which was set off like a jewel within glass containers.

In their technical virtuosity and inventiveness the Roman craftsmen were unsurpassed. We are told that 'In glass blown with or without moulds, in the decorative manipulation of the plastic metal, in cut and engraved designs, and even in painted and gilt decoration - in all these departments the glass made under the Roman Empire can show examples hardly surpassed at any later time.'¹⁴ The progress after the discovery of glass-blowing was very swift. For instance, 'By AD 40 artisans experimenting with mould-blowing methods had invented the

⁹ Enc. Brit., 'Glass'

¹⁰ Allen, Roman glass, 28

¹¹ Tait, Glass, 76

¹² Tait, Glass, 80

¹³ Sotheby, glass, 27

¹⁴ Honey, glass, 34

Roman 'prismatic bottle', which stands as the precursor of all subsequent glass bottles.... they were a more effective way of storing quantities of liquid than the traditional ceramic containers. They also fully exploited the qualities of blown glass: unlike other materials, it was impervious to oil and liquids, and could be easily cleaned and reused.¹⁵ The fact that 'that there has been no further change in the basic techniques since Roman days is one of the many indications of the modernity of Roman industrial processes.'¹⁶

Their skill is well described by Singer in a passage which shows how solid a technical foundation they laid for later developments. 'Roman workers of the first century A.D. were as adept at blowing a finely shaped vessel as any of their successors; and those of the second to fourth centuries A.D. could produce as elaborate a piece of glass as any Venetian worker of the Renaissance. They knew and used all the tricks of the glass-blower's trade. They could, for example, make flashed glasses of two or more layers; they could spin broad, flat dishes up to two feet or even more in diameter; they could insert one small jug within a larger one, and they could draw out hollow lobes from the walls of a vessel by the drop-on process.'¹⁷

Their technical ability meant that in terms of both the diversity of the objects which they made, and in the quantity, it could be claimed that Roman civilization was more glass-soaked than any other until the very recent past. This was partly due to the cheapness of the product arising from the technical developments. 'Every corner of the then known world [Roman] could be supplied with glassware at an almost disposable cost. Indeed, we know from fragments in middens and rubbish heaps that pieces were thrown away almost undamaged when they could have been repaired relatively easily - for it was cheaper and easier to buy a new glass.'¹⁸ So what was glass used for?

It was principally used for containers of various kinds. 'Although the range and number of shapes and types grew and changed, everyday domestic goods predominated, mostly plates, dishes, bowls, beakers, cups, bottles, jars and jugs, with an occasional lamp, inkwell, ladle or spoon.'¹⁹ McGrath suggests that 'their application of it for domestic purposes, architectural decoration and personal ornament reveals the most thorough comprehension of its possibilities in these directions. Glass appears to have been used in pavements and in thin plates as a coating for walls... in forcing frames and even in drain pipes.'²⁰ Early in the twentieth century an author argued that 'It may appear a somewhat exaggerated assertion that glass was used for more purposes, and in one sense more extensively, by the Romans of the imperial period than by ourselves in the present day; but it is one which can be borne out by evidence... for domestic purposes, for architectural decoration and for personal ornaments glass was unquestionably

¹⁵ Klein and Lloyd, 29-31

¹⁶ Singer, ii, 337

¹⁷ Singer, ii, 33k7

¹⁸ Encycl. of Glass, 34

¹⁹ Klein and Lloyd, 33

²⁰ McGrath, Glass in Arch., 29

much more used than at the present day.²¹ The reason for this, it is suggested, is that it provided an alternative to fine pottery and porcelain. 'It must be remembered that the Romans possessed no fine porcelain decorated with lively colours and a beautiful glaze; Samian ware was the most decorative kind of pottery which was then made. Coloured and ornamental glass held among them much the same place for table services, vessels for toilet use and the like, as that held among us by porcelain.'²²

The Romans were thus superb artists in glass and had available every technique needed for extending glass to all possible uses. Yet like all civilizations, they could only see certain uses for the substance, and in some respects what is most interesting is the absences in the Roman glass world, as much as the presences.

Of the five major uses which I have suggested, the Romans developed two in a superb way, that is verroterie (glass beads etc) and verrerie (glass vessels and other useful ware). Indeed, they thought of a number of uses which have since fallen on the way side, as we have seen, such as for pavements or wall coatings or drain pipes. But the other three uses, which would be the great development of medieval Europe, although perfectly practicable and indeed known about, do not seem to have been of interest. These are window glass (vitrail), mirrors and lenses. It is worth looking at these absences.

Windows

It is quite evident that the Romans could make good windows of glass, and occasionally did so. Window glass was apparently made by casting, and pieces of considerable size could be made. 'Some of the best evidence for early glass windows came from the Roman time capsule of Pompeii, buried under volcanic ash by the eruption of Vesuvius in A.D. 79. ... The largest window-panes at Pompeii were in the public baths - forty by twenty-eight inches and half an inch thick, mounted in bronze frames.'²³ Or again that we are told that glass 'in flat pieces, such as might be employed for windows, has been found in the ruins of Roman houses both in England and in Italy...the discovery of fragments of sheet-glass at Silchester proves that the process of making sheet-glass was known to the Romans.'²⁴

Yet a number of authors have been surprised at the slow development of window glass in Italy: 'their development of window glass seems to us unaccountably slow... It was used in windows, though not to the extent that it displaced mica, alabaster and shells.'²⁵ We are told that 'The Pompeian examples aside, window glass was relatively rare in the warm Mediterranean in Roman times. The reason for this is partly explained by looking northwards. Glass windows become 'more common as one moved north. Enormous glass factories were established at Trier

²¹ Enc. Brit., 'Glass'

²² Enc. Brit, Glass.

²³ ?? Thomas ??? James and Thorpe??)

²⁴ Enc. Brit., 'Glass'

²⁵ McGrath, Glass in Arch., 29

and Cologne, in Germany, during the second century A.D. In Britain glass windows were common after A.D. 50... and are found at many native settlements and even beyond the frontiers of the empire in southern Scotland.'²⁶

This suggests that the main reason for the absence of window glass in Italy was climatic, and it rightly directs our attention to the intersection between Roman techniques and the northern climate which would become so important later in the history of glass. But there may have been other reasons as well, as McGrath suggests in summarizing the situation with Roman windows. 'Though the Romans were well aware of the applicability of glass to windows they appear to have regarded any extensive use of it in this connection either as a luxury or as a necessity to be made a virtue of..' He continues that 'while it was fairly common it was not usual and that any employment of it by an important person called for special comment.' McGrath believes that 'It is probable... that the crudity of the glass was the real deterrent ...its imperfections led to its neglect by those who could afford it.' To this was added the fact that 'the climate of most Roman cities presented no special necessity for glazed windows.'²⁷ Furthermore, we should remember that glass is expensive to make, consuming large quantities of wood and labour. If it is not really necessary, given the climate, it would not be likely to be adopted.

Mirrors

It appears that the Romans, as well as the Greeks, knew how to make glass mirrors. Yet they were hardly ever made, metal mirrors being preferred. Honey wrote of glass mirrors that 'though these were not unknown to the Romans they were not in general use, those of polished metal apparently being preferred...'²⁸ We are told that mirrors from cast glass have been found in Pompeii, and there are other references also, yet the development of the widescale use of glass mirrors awaited developments in medieval Europe. McGrath writes that 'The employment of glass for mirrors, though known to the ancients, was only practised on a small scale. Little convex mirrors 1 1/2 in. in diameter have been found in Greek and Graeco-Roman tombs at Arsinoe in Egypt, their metallic backing still quite brilliant; otherwise metal mirrors, preferably of white bronze though of various other metals, were the rule.'²⁹

Roughly the same impression is given by an early overview of mirrors in antiquity. We are told that 'the mirror of the Etruscans, Greeks and Romans consisted of a thin disk of metal (usually bronze) slightly convex and polished on one side... a manufactory of mirrors of glass at Sidon is mentioned by Pliny (**Nat. Hist.** xxxvi. 66, 193) but they appear to have been little used (one has been found at San Remo). Glass mirrors were coated, but with tin; some silver mirrors have also been found. They are said to have been in use as early as the time of Pompey, and were common under the empire. Homer knows nothing of mirrors, but they are frequently mentioned in the tragedians onwards. The usual size was that of an ordinary hand-mirror, but in imperial times some appear to have been large enough to take in the whole figure... The first

²⁶James and Thorpe, *Ancient Inventions*, 464-5

²⁷McGrath, *Glass in Arch.*, 98

²⁸ Honey, *Glass*, 7

²⁹ McGrath, *Glass in Arch.*, 313

specimen of a Greek mirror was not discovered till 1867, at Corinth, and the number extant is comparatively small.³⁰ Thus the glass mirror is not a recent invention; but its widespread use, and the superb development of large mirrors, especially in Venice, did not occur until many centuries later.

Lenses

As yet I have little information on lenses in Roman times. We are told that 'its employment for optical instruments was only known in a rudimentary stage'.³¹ Honey believes that 'there is evidence that the mode of manufacture of glass lenses was mastered by the Romans though lost for a time in the Middle Ages.'³² It is claimed that they 'used a little glass ball, filled with water, as a magnifying-glass for fine work, such as the engraving of gems. They used a similar device as a burning-glass, and may have known something of lenses.'³³ In fact the use of glass filled with water was an earlier invention. 'The magnifying power of glass spheres filled with water was known to the Greeks. Some of their optical properties were elucidated by Ptolemy in the second century A.D. in his 'Optics'. Islamic writers developed the optical conceptions of the Greeks.'³⁴ But for various reasons neither they, nor the Greeks for whom it would have been even more interesting (but who pre-dated glass-blowing) developed lenses, prisms and spectacles in a serious way. Glass as a scientific tool, either in this way or in chemistry, does not seem to have been developed to any significant degree before its use by Islamic scholars from about the eighth century onwards.

³⁰ Enc. Brit. 'Mirrors'

³¹ Encyl. Brit. 'Glass'

³² Honey, glass, 25

³³ Wonders of Knowledge, 1962

³⁴ Singer, iii,229-230