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Glass bead making : some wound bead experiments

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RÉSUMÉ

Sur quelques sites scandinaves, datés du VIII[e] au X[e] siècle ont été découverts des perles de verre intactes et brisées, du verre brut, des objets semi-finis, des déchets et parfois des outils, ce qui semble indiquer une production locale de perles de verre. Une série d'expériences concernant la technique du tournage/enroulage ont été effectuées, et les résultats suggèrent divers types de fabrication des perles monochromes et polychromes. Les outils trouvés sont en nombre très limité ; or les expériences réalisées indiquent un besoin en équipement important. L'étude du savoir-faire préhistorique n'éclaire pas seulement les aspects technologiques, mais aussi les aspects socio-économiques, car il y a des raisons pour que deux, trois personnes ou davantage soient impliquées dans la production.

ABSTRACT

From a small group of Scandinavian sites dated to 700-900 AD, whole and broken beads, raw glass, semi-manufactured articles, waste and occasional tools seem to indicate local production of glass beads. A series of experiments have been carried out, and the results so far suggest methods of manufacturing several types of monochrome and polychrome beads. Contrary to the general interpretation, crucibles were not a necessity to the production. The number of tools found is very limited, and the experiments showed a demand for a wide range of equipment. Furthermore, the vitalization of the prehistoric craft has enlightened not only the technological details, but also the socio-economic aspects, as there are obvious reasons for involving two, three or more persons in the production.

Introduction

Many kinds of handicrafts including many different kinds of materials have been tested experimentally in the archaeological world during this century. Although glass is a well-known material from Prehistory, the making of glass and the manufacture of glass objects have never received any great attention from experimental archaeologists, perhaps because glass is a generic term for a whole range of different components which can be and have been manipulated in many ways according to raw materials, skills and tradition.

This paper deals exclusively with bead making in the Scandinavian tradition around 700-900 AD, on the basis of the material from seven sites showing traces of the craft. The technique is one of the most simple and widespread : winding. The testwork is not yet finished, and the following must be regarded as preliminary statements for discussion[1].

Glass – and how to work it

Glass is made from three main ingredients, silica oxide, SiO_2 (sand) and fluxes which can be sodium carbonate, $NaCO_3$ (soda) or potassium carbonate, K_2CO_3 (potash). Calcium carbonate, $CaCO_3$ (lime) acts as a stabilizer, and lead oxide, PbO both as a stabilizer and a flux. The proportion between these varies according to geography, time and tradition. Other (metal)oxides are to be found in ancient batches according to impurities in the raw materials or as deliberately added colourants, decolourants or opacifiers. Most archaeological research in glass composition has focussed on these variations from the visual point of view, while the importance and influence of the working conditions have never been a question of great interest. However, the latter aspect is of importance when working with glass, not only with respect to furnace construction, but also when handling the hot glass.

Pure silica has a melting point above 1 700° C, which can be lowered to around 1 300° C by adding the fluxes (Frank, 1982 : 10). The amount and kind of flux will determine the working conditions. The more lead and soda (and less silica), the easier and longer the working time. But since less silica means less durable glass some outer limits cannot be exceeded. The melting temperature is much higher than the working temperature, which on the other hand can vary according to the working technique. Blowing demands temperatures around 1 200° C, because raw glass (the batch) must be quite liquefied when gathered on the blowing iron. Slumping and fusing can be carried out at about 800° C, which makes the cold glass pre-placed in a mould flow into shape. Solid work such as wound bead making needs temperatures ranging from 800-900° C when the raw glass is remelted and manipulated directly (like free-blown glass). All kinds, of freemaking techniques require the use of tools during production. Any contact between tools and glass will cool the latter, so reheating is a necessity, and the furnace construction of great importance, especially because the temperatures must be held during long periods, which demands fuel on a large scale. Some kind of temperature control is also needed for the annealing of the finished pieces, most important to hollow ware and/or blown pieces ; whereas smaller items as beads are more tolerant in regard to annealing temperature and rate.

Archaeological evidence – and some interpretations

Kaupang (Norway), Helgö, Birka, Paviken and Åhus (Sweden), Haithabu (Germany) and Ribe (Denmark) are all sites characterized by traces of trade and craft and situated near the open sea or main waterways (fig. 1).

The material is primarily glass in a variety of colours and colour combinations, whole and broken beads, raw glass, threads (some twisted), mosaics, different kind of waste and a range of indefinable molten items (Callmer, 1982, 1988 ; Dekówna 1978 ; Frandsen, Jensen, 1988a, 1988b, 1988c ; Hougen, 1969 ; Jørgensen, 1982 ; A. Lundström, 1976, 1981 ; P. Lundström, 1981 ; Näsman, 1979).

Tools are seldom found. A metal point with a square cross section and hollow in one end was found at Paviken, and also some glass fragments with burnt clay which have been interpreted as crucible fragments (P. Lundström, 1981 : 100). A bead from Helgö found with a metal point in the hole might be interpreted as a bead mandrel. Also some 30 fragments of crucibles with green glass were found at Helgö (A. Lundström, 1981 : 17). During excavations in Ribe several « working

(1) All the experiments have been carried out at the Institute of Prehistoric Archaeology, The University of Århus, and at the Historical-Archaeological Experimental Centre, Lejre, Denmark.

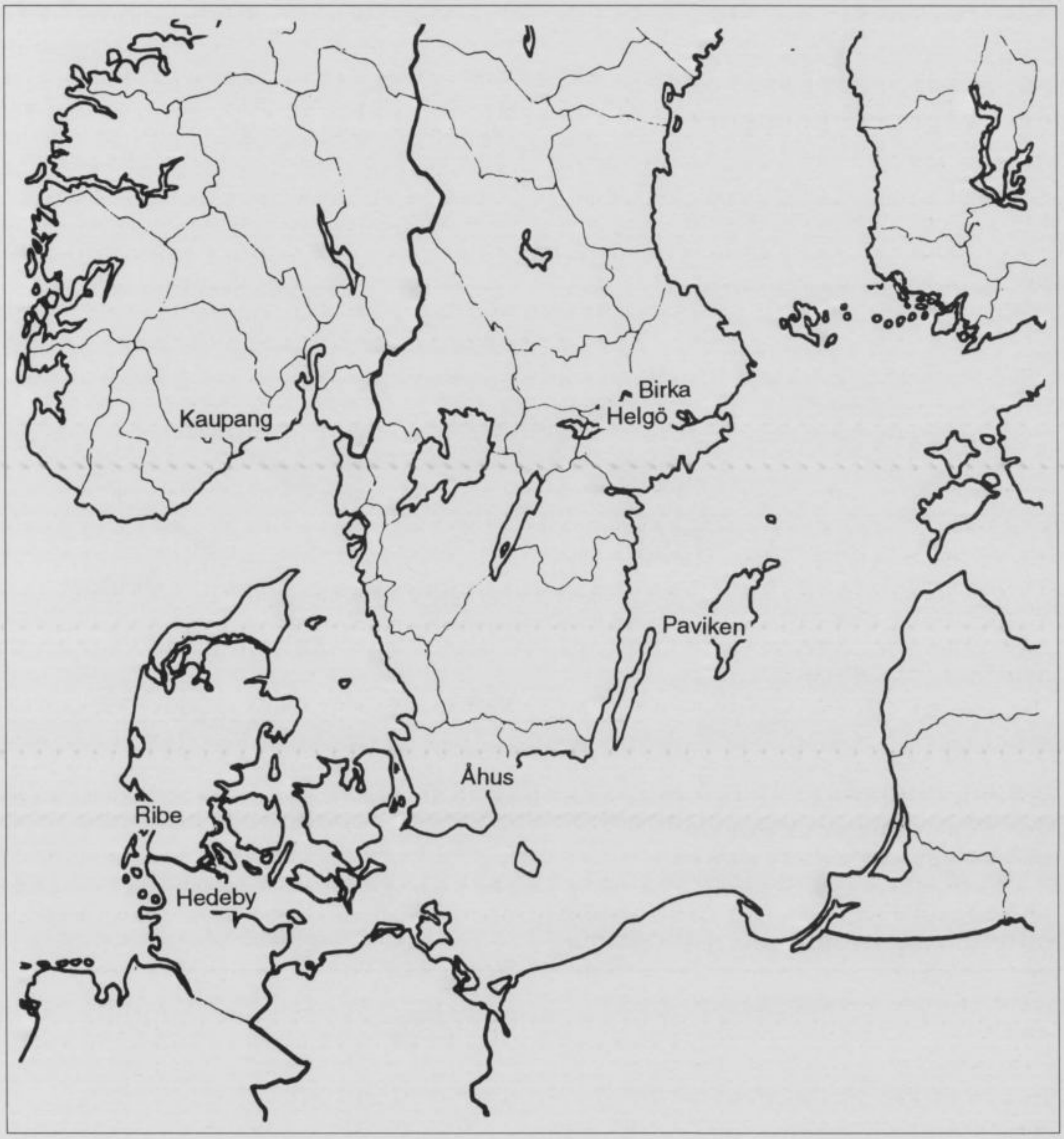

Fig. 1. Scandinavian sites with traces of glass beadmaking 700-900 AD.

horizons » including fireplaces were found. In connection with these a stone with a hollow, a spoon shaped piece of antler, a small iron pan, and as a stayfind a pointed metal stick with a (broken ?) wooden handle were found (Näsman, 1979 : 131). Regarding actual objects as well as excavation conditions the Ribe finds are the most informative so far and they have played a major role in the experiments.

On the basis of the material some interpretations concerning methods of manufacture have been put forward. For instance P. Lundström, who believes beads could be made from glass in crucibles by « pulling threads which were wound around a metal stick » (trans., *op. cit.*). The division of the procedure, even more radically, into a thread-pulling workshop and a winding workshop is suggested by Z. l'Vova (1970 : 121). Perforation seems to be a keyword for some archaeologists, *e. g.* P. Lundström also suggests the « making of glass balls which afterwards were perforated with a metal point while hot and soft » (trans., *op. cit.*) ; or as A. Lundström writes, « perforation of hot glass drops » (trans., 1976 : 10). Mostly, the technique is referred to as some kind of winding or as « Roll-technik » (Näsman 1979 : 131). Tools are seldom mentioned, but J. Callmer suggests a metal point with some kind of separator, a marver, and the possible use of moulds in connection to the *millefiori* technique (1982 : 150). Almost all descriptions include (directly or indirectly) the use of crucibles, *e. g.* « in crucibles of clay, tesserae and glass sherds were melted, and the colour of the batch was adjusted by adding tesserae of the desired colour » (trans. Jørgensen, 1982 : 89).

Regarded as a whole the interpretations of the archaeological finds consist of only vague formulations and few descriptions of the actual processes.

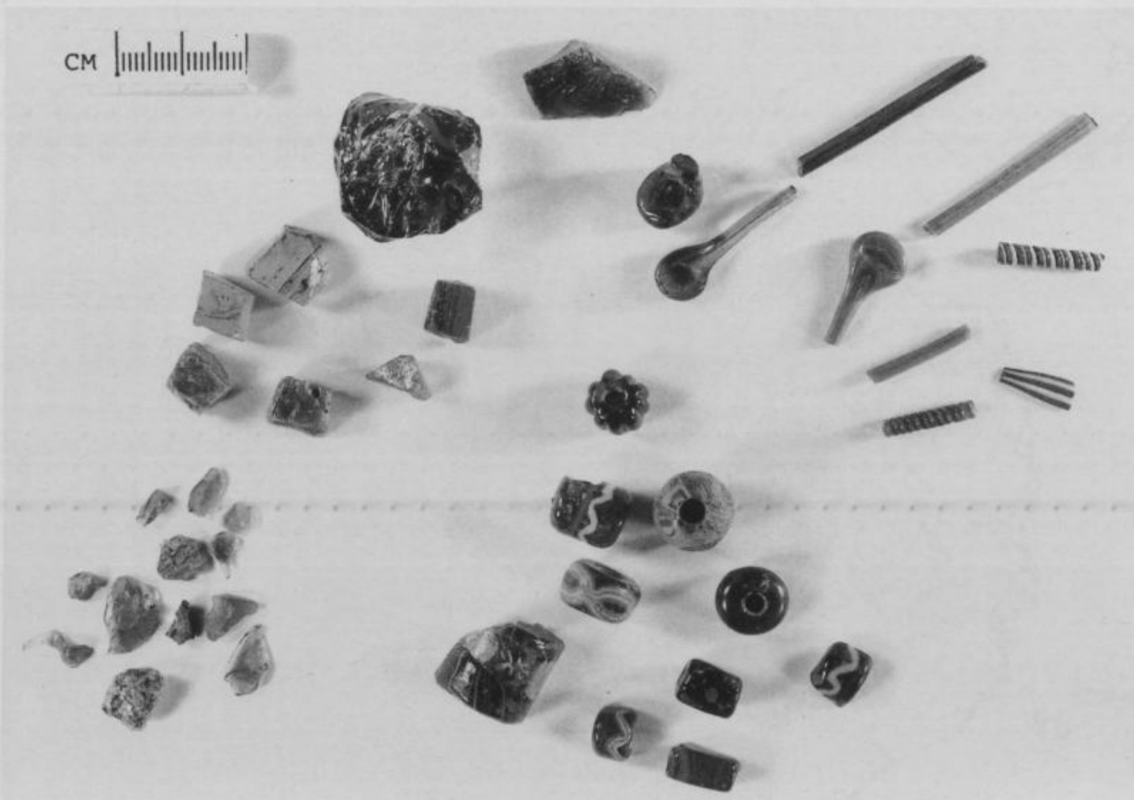

Fig. 2. Glass from Ribe. Clockwise from left : waste, raw glass, tweezer marks, rods, threadband and beads.

Some result from the testwork

The descriptions are divided into two major parts. One concerns the actual methods, *i. e.* how some of the bead types represented in Ribe were constructed ; this is followed by some considerations concerning selected elements as crucibles and furnaces.

The first method to be tested was the pulling out of threads, which I attempted to wind around the bead mandrel. This proved to be impossible and seems more time – and fuel – consuming compared to the method of simply heating a lump of glass until it is almost « dripping » and then make the bead by winding the « drop » around the bead mandrel (fig. 4). Simple monochrome beads were made in this way. Another common and simple shape found in Ribe is the cylindrical bead, monochrome as well as polychrome thread decorated (fig. 3). The shape was created by marvering the hot bead on a flat surface, in this instance polished granite. A typical type of bead from Ribe is the blue melon bead. In the testwork the incisions were made by a knife with a cut edge, which left the

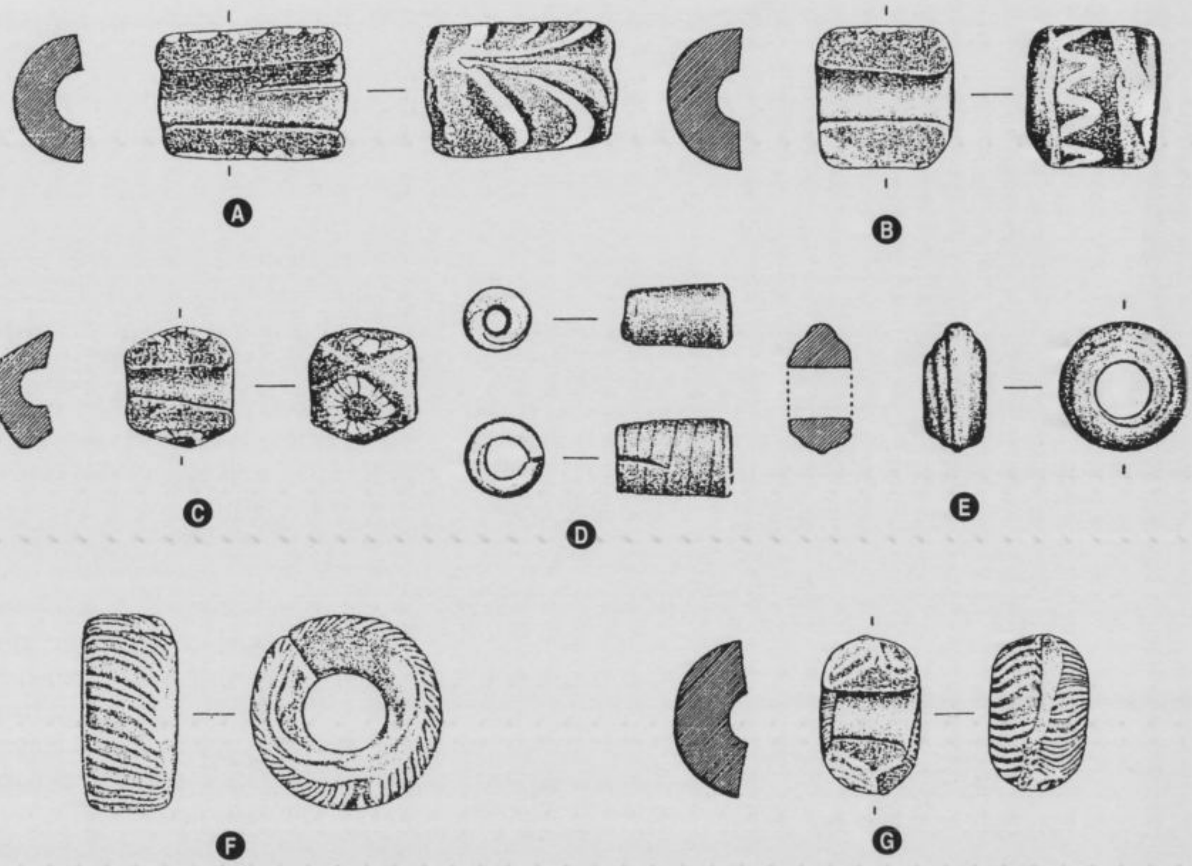

Fig. 3. Beads from Ribe. **A.** Thread-decorated bead with combed pattern. **B.** Thread decorated bead. **C.** Polyhedric bead. **D.** Cylindrical bead. **E.** Annual bead. **F, G.** Reticella beads.

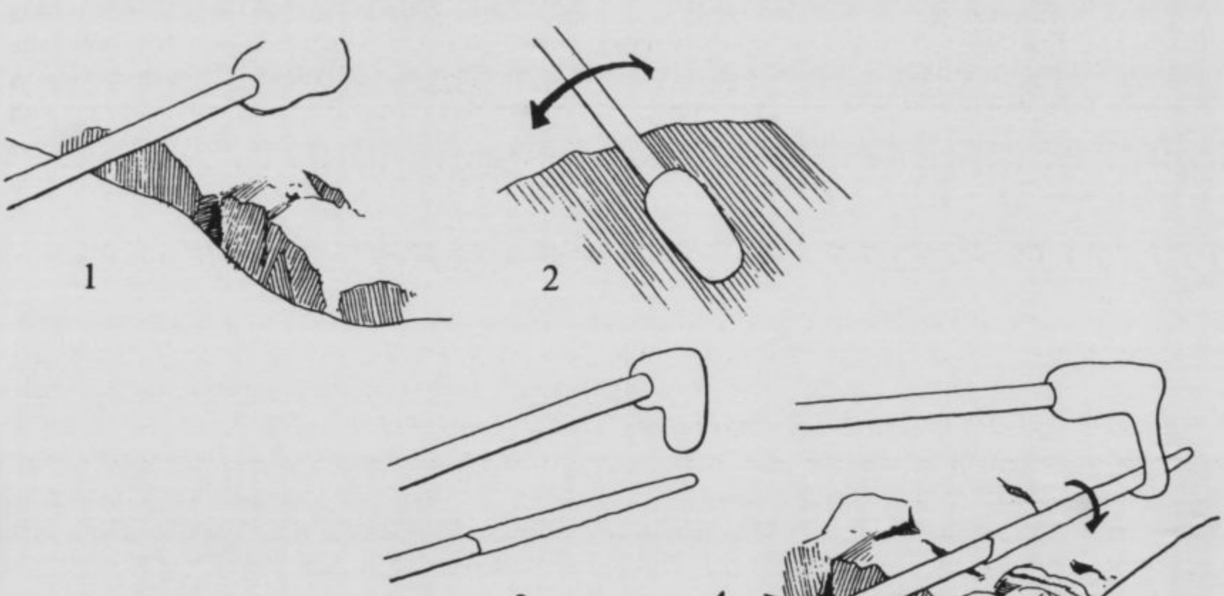

Fig. 4. How to make wound beads : a gather on a pontil is heated until very soft and then wound around the bead-mandrel.

bead globular (fig. 5). If a straight edge was used the bead tended to become cylindrical. The incisions had to be made all « in one go », because reheating would cause deformation. Melon beads from Ribe showing less and less marked incisions suggest similar methods and problems.

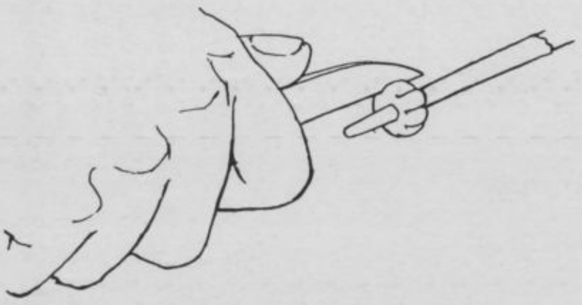

Fig. 5. Incisions on melon beads made with a knife. After shaping the beads were placed to anneal using the annealing tong.

The thread-decorated beads found in Ribe were presumably also made locally, and in the testwork they were made as follows : a thread was pulled from a small gather by using a pair of tweezers (fig. 6). The tweezer mark was broken off and the thread melted onto the bead. A typical waste product from this method was the tweezer marks which have identical parallels in the archaeological material, even the characteristic break caused by the cooling grip of the tweezer (fig. 7). But as I proceeded, more skilled threads could be drawn directly from the gather without using the tweezers. The influence on the waste is obvious, and one can ask whether the archaeological tweezer marks are to be related to this particular bead type. If so, one should expect a colour combination similar to the thread colours, *i. e.* white, red and yellow ; but instead many monochrome tweezer marks from Ribe are blue and green, as are most of the beads.

Evidence for the threadband-decorated beads was not only whole and broken beads, but also loose threadbands in the same colours, *i. e.* white, red and yellow. Several of the loose threadbands were made by melting preheated rods on a small gather of blue glass (fig. 8). The problem so far is to make the bands run in zigzag without turning the blue backside upwards.

The making of reticella beads is indicated from loose threads, all made from a blue core thread and white, red and/or yellow threads. Polychrome tweezer marks in the same colours were also found. From the broken beads it is possible to see how this type was constructed : on a blue bead two reticella threads are wound carefully and almost without any overlapping. Most of the beads have a red thread covering the junction.

Several methods of making the reticella beads have been tested, one of them being marvering pre-heated rods on a blue gather, using the iron pan as a marver. This use of the pan for marvering has also been suggested by archaeologists (Roesdahl, 1980 : 115), but the testwork clearly proved this to be inexpedient, since the rim of the pan hinders the right angle (0°) for marvering. A small oval iron plate has been found in a « pit with

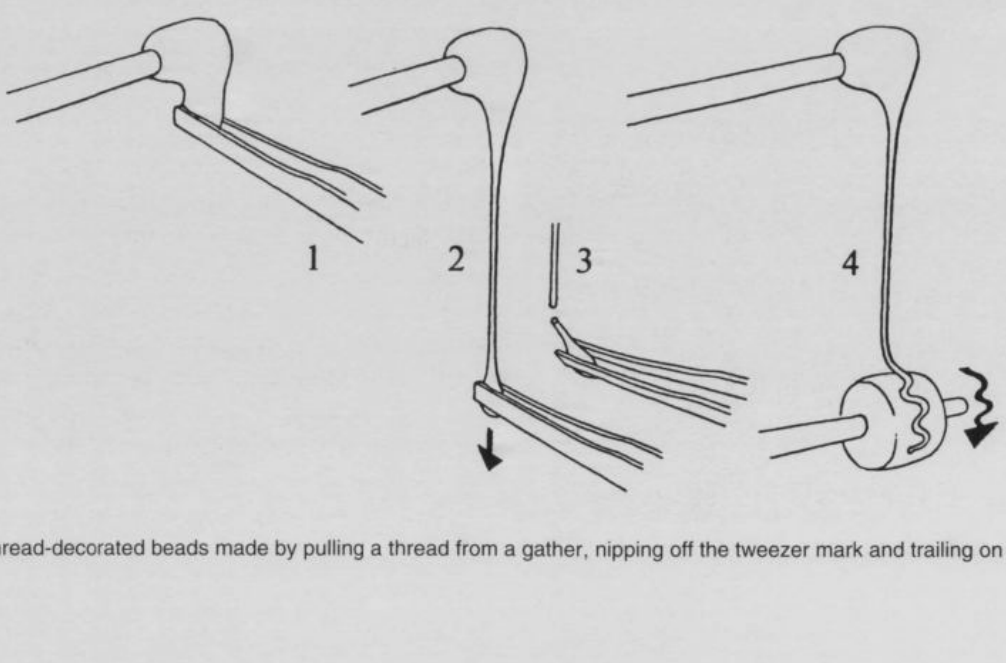

Fig. 6. Thread-decorated beads made by pulling a thread from a gather, nipping off the tweezer mark and trailing on the thread.

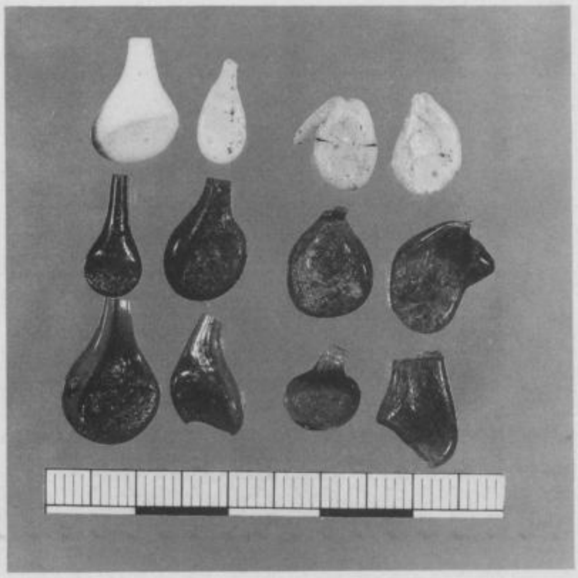

Fig. 7. Tweezer marks from Ribe (right) and from the experiments (left). Notice similar breaks due to the cooling effect from the tweezer (bottom row).

Fig. 8. Threadbands made by melting pre-heated rods of white and red glass on a small gather of blue glass.

glassworking debris » in Armagh, northern Ireland (Youngs, 1989 : 205). Such a plate would be far more acceptable in this connection. Another method tested was to « shear on » the white threads using a pair of scissors. This prevented deformation of the reticella cone, a phenomenon which cannot be avoided when marvering. Using the tweezer to grip and pull out while rolled, the thread was twisted (fig. 9). Having wound the reticella thread around a blue bead the shears were used to cut off the thread and prevent overlap. This looked quite convincing on the finished beads, but so far no archaeological waste showing cutting marks like the replica waste have been found.

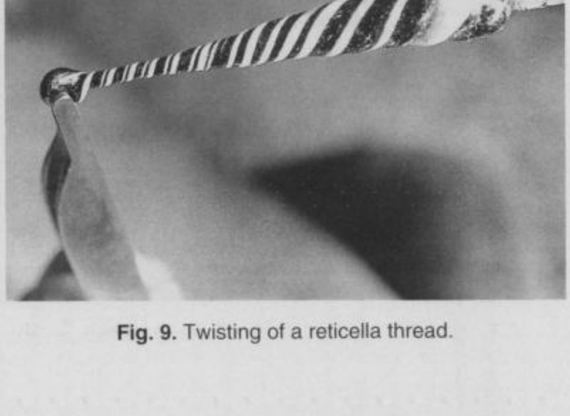

Fig. 9. Twisting of a reticella thread.

Fireplace or furnace ?

Using solid technique like wound bead making is a pre-condition to keep temperatures around 900° C during long periods. The heating source and pyrotechnology play a central role, but are often neglected in the archaeological research. In his article « Glass furnaces through the ages », R. J. Charleston pays only minimal attention to the kind of fireplace or furnace which must have been in use during the first 1 700 years of glass manufacture, and he presumes that « no really high temperatures can have been attained » (1978 :)). Although the evidence from glass workshops is not numerous, the statement was easily refuted. The fireplaces from Ribe were only to be seen as concentrations measuring 25-30 x 50-60 cm of red-burnt clay, charcoal and glass waste (Näsman 1979 : 125). For the testwork, so far, small open fireplaces of the same dimensions have been used, made from stones in a circle covered with sand-mixed clay and having a pair of bellows or artificial bellows to raise the temperature. Charcoal from hardwood was used as fuel. Temperatures around 1 000° C were easily reached, and keeping the temperature was only a question of fuel and manpower.

One of the practical problems was to avoid charcoal and ash sticking to the molten glass. Even though such small impurities are to be seen in the Ribe material as well, most of the ancient beads have bright shining surfaces. To move the heating centre to above the charcoal – which would prevent most of the impurities – a higher and more closed construction must be used. So far a piece of wood has been placed on the rim of the fireplace, which also prevented too much loss of heat. Such a high furnace construction has been used in recent times in Nigeria. Here a conical furnace, around 50 cm high, forms the glowing centre for 3-5 persons making beads and rings. One person pulls the bellows, and wood is used for fuel (Dubin, 1987 : 123 ; Gardi, 1974 : 87). Another argument against the low fireplace is the glazing of the bottom, which arouses because the nozzle was placed at the same level. Since glazing was not found on any of the fireplaces in Ribe, one could presume the use of a higher construction there. Future investigation has to concentrate on this subject.

Reconstructions and replicas

The turning of theory into practice creates many questions and problems. The ideal situation is working only with replicas, *i. e.* an identical recreation of an object ; but when the archaeological evidence is poor, one may also include the use of objects reconstructed from direct or indirect traces. When working on glass the dividing line between reconstructions and replicas is roughly to be drawn between the tools and the raw glass. Since evidence for glass bead making tools is also very limited, and glass can be shaped in similar ways using a variety of tools, the actual reconstruction of a tool is not so important, as long as the impressions in both the ancient and recent glass are the same. This applies to both the tweezers and the annealing tong, the first being a replica of a modern tweezer, the latter provided with a wooden handle which proved workable. Far more essential is the composition of the raw glass, which is closely related to the different working conditions according to the major flux. The importance of an actual batch must be underlined.

Unfortunately, the testwork has been carried out using modern glass so far, which of course makes certain reservations concerning the results. Only a limited range of the Ribe glass has been analysed (Henderson and Warren, 1983 ; Gam, 1989), which makes only provisional interpretations possible. Not unexpectedly, there are great differences between the colours ; *e. g.* the content of calcium is low in green, red, yellow and orange coloured glass, and high in white and blue glass. The lead content is only high in yellow and orange glass. Soda must have acted as a flux since the content of sodium ranges between three to ten times the content of potassium. Only in the blue and white glass the proportions are reversed. This is in contrast to modern glass which has a high content of lead, potassium and zinc. Some of the test beads also have a metallic surface not found on the ancient beads, which might be due to the combination of a high lead content and a reducing atmosphere. Estimating the prehistoric working conditions one would expect a rather fast setting glass, leaving only very limited time for manufacture. Although not all the colours used in the testwork have been analysed, the main impression of a far more workable glass seem obvious. Investigations concerning actual working conditions and exact temperatures, which also affect the construction of the furnace, demand the use of replica raw glass. However, for that purpose more analysis of the glass has to be carried out.

The question of crucibles

As mentioned above most archaeologists suppose that crucibles are a necessity for beadmaking, presumably because of the possible crucible fragments found at Helgö, Paviken and as stray finds on Gotland (Nerman, 1951 : 253 ; Biörnstad, 1955 : 937). Also four fragments were found in Ribe, but not in connection with the workshop horizons (Näsman pers. comm.). A great part of the testwork has been devoted to the use of crucibles, and several arguments against their necessity are put forward here. First of all, the demand for fuel and raw glass is high. When melting the glass in a crucible a certain amount will always be left unusable. This seems unwarranted, if one regards glass to be an « expensive » raw material, all of which had to be imported. Furthermore, the high temperature glazes the surface of the crucibles, which makes them very durable and not easy to destroy. One should expect to find a higher amount of fragments in areas with other material preserved. Additionally, elemental analysis should be carried out in order to establish the composition of the « glass » inside the archaeological crucibles. The only fragment analysed so far is from Ribe, and it is covered with a thin layer of yellow glass with a remarkably high content of tin (16,3 %) and a very low content of silica (26,7 %) (Henderson and Warren, 1983 : 176). Whether this is a glass with a very special composition or whether some exchange mechanism between glass and crucible components has taken place cannot be determined. Such an exchange mechanism seems to be proven on a crucible fragment from London dated to the first or second century (Heyworth, forthcoming). Also the composition of the crucible components should be analysed in order to determine whether local or imported raw material has been used, as shown on some English finds (Freestone and Tite, 1986). Thus, more chemical and physical analyses are needed to prove any definite connection between crucibles and wound glass bead making. However, glass beads can be made without using crucibles. If glass is heated to around 300° C it can be melted directly onto a pontil (a solid iron stick) and shaped into a gather[2]. The actual making of a bead is when some of this hot glass is wound around the bead mandrel. During the experiments small pieces and fragments of raw glass were put on the iron pan. The pan was placed on the rim of the fireplace. In this way a gather could be made using less glass and fuel than demanded for the crucibles (fig. 10).

Fig. 10. How to make a gather : raw glass is preheated on the iron pan and melted directly on the pontil.

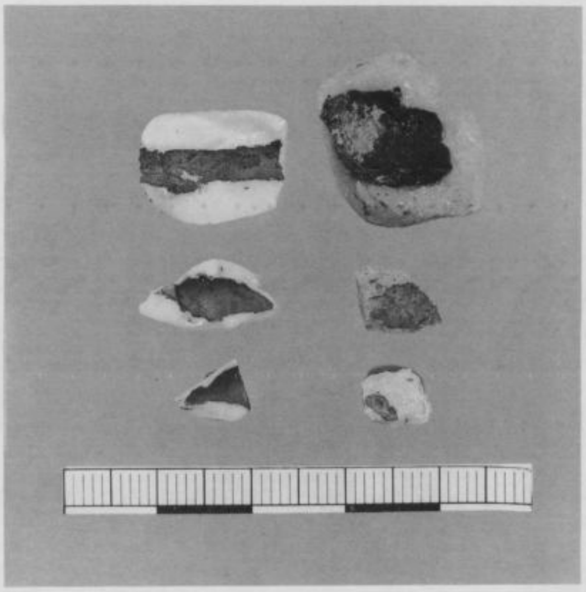

Fig. 11. Pontil-glass, *i. e.* the innermost layer of glass containing scales of iron from the pontil. From the experiments (left) and from Ribe (right).

About pontils and pans

In connection with the use of a pontil, a kind of waste glass was produced, namely the innermost layer of glass, which contained iron scales. Because of the iron left from the pontil, this glass could not be reused. Similar glass waste was found in the Ribe material, the first to be identified (fig. 11).

When using the pontil-gather method, the glass was pre-heated on the small iron pan. The one from Ribe was found standing upright in one of the fireplaces, and from Ireland similar and more sophisticated and decorated pans have been found in connection with glass bead making material (Youngs, 1989 : 207). A function as that described for the testwork is very likely, whereas proposals like marvering or melting pan have proved inexpedient.

(2) This modern term is used for the lump of glass on a pontil or blowing iron which is gathered from the pot or tank furnace.

Present and future prospects

Though far from all questions concerning wound glass bead making have been answered, the experiments have shown that some interesting and unexpected results can derive from an archaeological material when adding technical knowledge and skills. For the bead types tested, especially reticella beads need further examination. Other types of beads from Ribe which have been tested only cursorily are polyedric beads with « eyes » ; beads with a combed pattern and imitated segmented beads. Beads with a plastic thread decoration have not yet been tested, no have mosaic beads. Microscope observations of the first type showed that the three threads are trailed on in one continuous process. Mosaic beads represent an entirely different and perhaps more complicated method of manufacture, but regarding the semi-manufactured articles, the waste and whole and broken mosaic beads, this type was probably also made in Ribe. As the technique presumably includes some kind of mould use, the resemblance to fusing is interesting, because it might demand some other construction of the furnace than required for winding technique. Apart from the actual methods, other subjects are important to elucidate. In some beads remnants of some kind of separator are observed, and one bead has been analysed[3], for which reason different kinds of clay have been tested. A slurry of kaolin was the most successful, but the high content of alumina in this type of clay does not correspond to the analysed separator. In some beads thin iron scales are observed, which might indicate the lack of separator, but more tests are needed.

For annealing two methods were tested. The first was to place the beads in the pan on the rim of the fireplace. At the end of each test session the pan was placed directly in the live coals and left there to cool concurrently with the coals. This proved satisfying, but, to prevent undesirable cooling during the time of production, annealing in warm ash and sand was tested as well. Since more experiments are to be done, no clear conclusions can be drawn yet. Especially the use of replica glass is important in this connection. Regarding the reconstruction of the workshop as a whole, many interesting topics arise. Identification of the archaeological material in order to determine the actual workshop or manufacture waste is very important.

Often, the glass material is interpreted quantitatively – attaching too much importance to the presence of one single type. So when a local production of beads on the island of Bornholm, Denmark, is stated because of two mosaics found in a grave (Jørgensen, 1982 : 93), the basis seems most inadequate. Instead, the glass should be regarded qualitatively, because several types might be recycled. This counts for all monochrome glass such as threads, tweezer marks, and raw glass, whereas polychrome threads, tweezer marks, beads and glass with impurities (iron scales from the pontil or ash from fireplace) cannot be reused. There is no obvious reason to remove the latter group from the workshop area, for which reason their presence might indicate production.

Vitalising the craft illustrated the advantage of more persons being involved on the production. Although it is much a matter of skill and experience, many processes can be carried out more easily if one or two persons participate. This applies to thread (band) decorated beads and reticella beads, especially if shearing is to be used for the latter. Regardless of the size of the manufacturing team, at least one person is needed for pulling the bellows. In this way the testwork is also a basis for discussions concerning social organisation and socio-economic integration. How can we imagine the glass bead making craft carried out in Scandinavia during the late Iron Age and the early Viking Period ? Was it the « lonely wanderer » or was it a team – a family perhaps – working on markets only ? And how is it that the blowing of glass was a widespread craft from the British Isles across the European continent to the Black Sea since the first century AD, but presumably was not introduced in Scandinavia until the Middle Ages ? An obvious topic for future investigation in prehistoric glass technology is a closer examination of blown glass, enlarging the complex of questions concerning glass bead making.

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(3) The major element was silica, plus minor parts of alumina, and only traces of potassium, calcium and titanium (Gam, 1989).

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