

Composition and shapes of glass of the early medieval period (8th to 10th century AD) in Central Europe

I. Krueger*,
K.H. Wedepohl**

1. Composition (K.H. Wedepohl)

Glass production in the early medieval period took advantage of the glass composition and technical experience of the Roman imperial period. Apart from the large variety of shapes and colours the initial composition of Roman glass was always the same. For more than four centuries it was based on a constant proportion of mineral soda (trona), quartz and lime. The low concentrations of magnesium and potassium in Roman soda lime glass in contrast to earlier, contemporaneous and later soda ash glass (as analysed by Brill 1999) is obvious from fig. 1. Soda ash glass from the Mesopotamian, Egyptian, Sasanian and Islamic periods were made from saline plants of tidal flats and deserts. Some chemical information about these plants, which have a higher magnesium and potassium content than mineral soda, is represented in fig. 1 as crosses.

The post-Roman glass production in Europe in the first millennium was mainly based on soda lime composition. Fig. 2 contains plots of 6 groups of post-Roman soda lime glass samples taken from excavations of Levantine, Frankish, Anglo-Saxon and Carolingian glass workshops, tombs, palaces and monasteries. The average chemical composition of these groups does not exceed the small range of variation of Roman glass represented by the grey areas in fig. 2. These grey areas are based on 23 plots in fig. 1 from a compilation of 781 samples of Roman glass listed by Gaitzsch *et al.* (2002). Early medieval soda lime glass contains on average more calcium and less sodium than Roman glass. Within the six groups of post-Roman glass, the group of the 6th and 7th century AD from the Levantine region has the lowest sodium (and manganese) concentration. Because of these chemical characteristics it can be excluded that a major proportion of Levantine raw glass has been exported for contemporaneous European glass working. The soda lime glass production of the first

millennium probably depended completely on the long distance trade of mineral soda (trona) from Wadi el-Natrun in Egypt. This trade apparently declined to a certain degree towards the end of the first millennium but continued in smaller quantities till the end of the 18th century (Andréossy 1823).

The continuous demand for glass in the Carolingian period caused some glass workshops north of the Alps to convert their production at least partly to domestic raw materials. Ash from trees contains potassium plus lime instead of sodium plus lime in ash from halophytes, which was mainly used in antiquity and the first millennium AD. The former composition allows for the manufacture of a new glass type exclusively from wood-ash and quartz. This wood-ash glass is distinctly less resistant to weathering than soda glass. When excavated, wood-ash glass usually contains more or less thick layers of weathered material. To recognise its original composition, the unweathered glass core of the object has to be analysed by electron micro-probe. The oldest well-dated fragments of the new glass composition were detected by Wedepohl *et al.* (1997) in the destruction layer of AD 778 from the burning of the imperial palace at Paderborn excavated by Winkelmann. This palace of Charlemagne was destroyed by attacking Saxons shortly after its construction. We have collected chemical data from about 20 samples of wood-ash glass fragments from vessels, panes and linen smoothers dated from shortly before AD 800 to about AD 1000. In addition to fragments from Paderborn, other samples were taken from the Carolingian monasteries of Corvey, Brunshausen and Lorsch, from the Viking trading site of Haithabu and the settlements of Hoexter, Drudewenshusen (Germany), Rouen (France), Beverley (England) and Borg (North Norway). Chemical data for our fig. 3 were provided by several authors listed in the caption of this diagram. The majority of this early medieval wood-ash glass is characterised by a distinctly higher

* Rheinisches Landesmuseum Bonn, Fraunhoferstr. 8, D-53121 Bonn, Allemagne.

** Geochemisches Institut der Universität Göttingen, Goldschmidtstrasse 1, D-37077 Göttingen, Allemagne.

23 Groups of Roman Soda Lime Glass

from Israel, Tunisia, Greece, Yugoslavia, Italy, Switzerland,
France, Germany and England (781 samples)

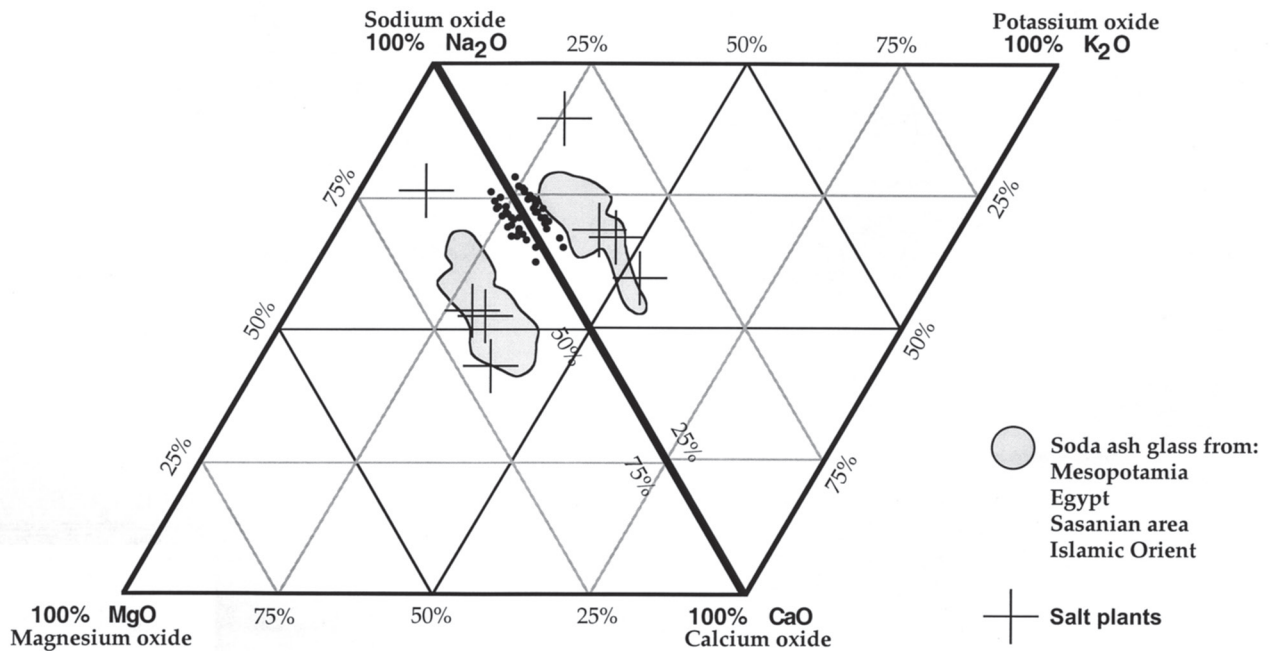


Fig. 1 — Representation of the major compositional groups of glass types in Antiquity. The diagram is based on the compounds Na_2O , CaO , MgO and K_2O from chemical analyses. These elements are specific for classification. The grey areas for soda ash glass and the crosses for beach and deserts plants are characterized by higher MgO and K_2O concentrations relative to Roman and other soda lime glass made from mineral soda (trona). The latter composition is plotted as filled circles. The two triangles forming the diagram are constructed from an extrapolation of the analytical data for individual samples or sample averages within two groups; $\text{Na}_2\text{O} + \text{CaO} + \text{MgO} = 100\%$; $\text{Na}_2\text{O} + \text{CaO} + \text{K}_2\text{O} = 100\%$. Data on the average composition of 16 groups of Roman soda lime glass from Europe are taken from a compilation by Gaitzsch *et al.* 2002. Additional data on Roman glass from Jalame are reported by Freestone, Gorin-Rosen 1999.

calcium to potassium ratio ($\text{CaO}/\text{K}_2\text{O}$) than samples of the later medieval age contain. The monk Theophilus reported in his *Schedula de diversis artibus* in about AD 1100 that wood-ash glass should be produced from two parts of ash from beech trunks and one part of quartz. The grey areas in fig. 3 represent glass compositions of the later medieval age from the respective materials in the same proportion as described by Theophilus. Wedepohl (1998) reported on the composition of wood-ash glass from Corvey, Hoexter, Brunshausen and a glass workshop in the Bramwald mountains dated from AD 1150 to AD 1450. However the early medieval glass workshop probably used a higher proportion of ash from beech twigs and bark as well as from ferns. From this source, they got the high $\text{CaO}/\text{K}_2\text{O}$ ratios and magnesium concentrations characteristic of early medieval in respect to late medieval glass. The relatively high CaO concentration exclusively in early medieval wood-ash glass required higher furnace temperatures than for the Theophilus type glass. It apparently needed advanced technological skill. Therefore, the early wood-ash glass production was probably located in the western part of the Carolingian empire, where the

Roman tradition was directly proliferated. This assumption has been confirmed by the recent discovery of numerous linen smoothers of the 10th century consisting of wood-ash and lead glass in several parts of France (personal communication B. Gratuze).

Early medieval glass workshops produced a small proportion of mixed wood-ash soda glass to save valuable soda. Different degrees of blending soda lime glass with wood-ash raw glass up to a proportion of one to one were recently discovered by us in material from the new excavations at the Carolingian monastery of Lorsch. It was probably produced in a local workshop there. Wood-ash glass and wood-ash lead glass in the shape of linen smoothers were traded by the Vikings. One hundred such smoothers were excavated at Haithabu in northern Germany as the only items consisting of wood-ash glass besides more than 7000 beads, 400 vessels, 25 pane fragments and 1100 unidentified objects made of soda ash and soda lime glass (Steppuhn 1998; Dekowna 1990). High-lead glass in small objects such as finger rings, bracelets, beads, etc. have been mentioned for the 9th and 10th century in England and in eastern Europe by Bayley (1990)

Early Medieval Soda Lime Glass

from the Levant and Europe (number of samples in brackets)

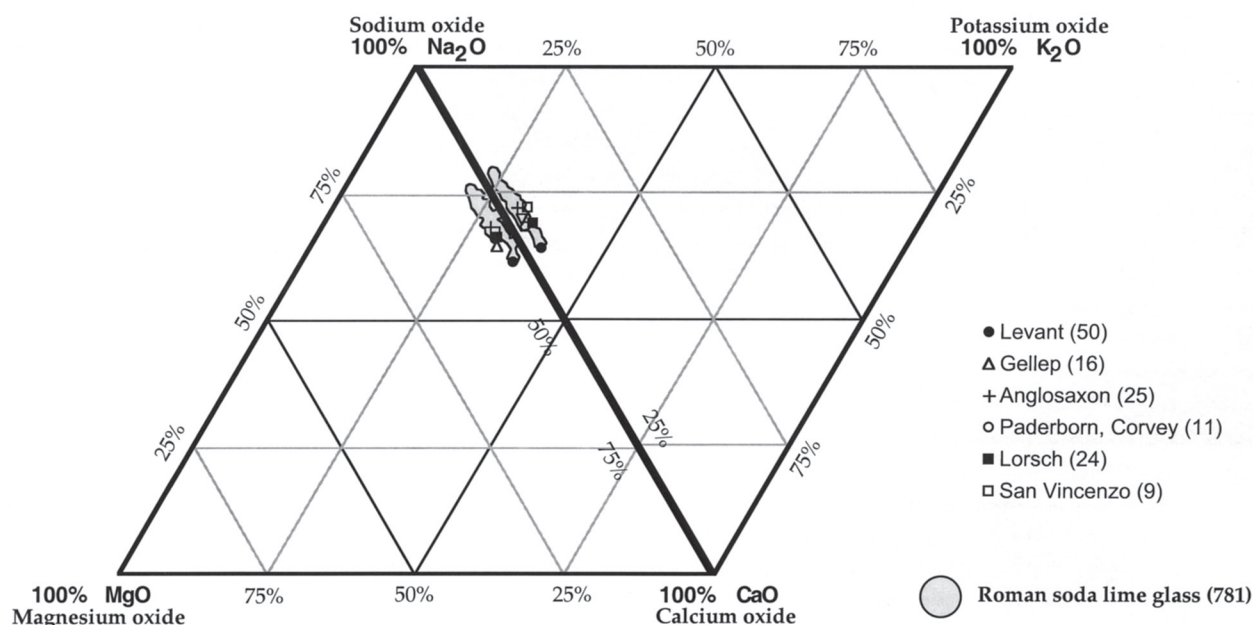


Fig. 2 — Representation of medieval and Roman soda lime glass compositions. The former contains on average more calcium and less sodium than the latter. The diagram is based on the compounds Na₂O, CaO, MgO and K₂O. The respective elements are specific for classification. The two triangles forming the diagram are constructed from an extrapolation of the analytical data for individual samples or sample averages within two groups: Na₂O + CaO + MgO = 100 % ; Na₂O + CaO + K₂O = 100 %. Data on Roman glass are the same as for fig. 1. Data on medieval glass from different sites are from the following authors: Levant : Freestone, Gorin-Rosen 1999; Gellep : Wedepohl *et al.* 1997 ; Anglo-Saxon: Freestone *et al.* 1999 ; Paderborn : Wedepohl *et al.* 1997 ; Corvey : Stephan *et al.* 1997; Lorsch : Sanke *et al.* 2002 and San Vincenzo : Freestone, Bimson 1996.

and Bezborodov (1975) respectively.

Production of soda ash glass as the earliest material in glass history was readopted and expanded considerably in the Islamic countries towards the end of the first millennium AD. Gratuze and Barrandon (1990) report that the change from soda lime to soda ash glass occurred in Islamic glass weights between AD 850 and AD 950. A majority of glass objects excavated at the Viking site of Haithabu, active from the 8th to the 11th centuries, consists of soda ash glass (Dekowna 1990). The shipwreck of Serçe Limani off the south-west Anatolian coast dated to about AD 1025 contained more than 3 tons of cullet, glass vessels etc. It probably traded its major load of soda ash glass from Islamic centres of glass production.

Early medieval glass workshops in Europe north of the Alps introduced wood-ash glass, which later became the standard composition of a relatively large glass consumption beginning in the 12th century. The yield of potash from a tree is very small. The production of one kilogram of wood-ash glass required about 200 kilograms of beech logs. This high quantity of wood for ash and fuel caused the glass factories to move from monasteries and settle-

ments into forests. In later medieval times, a minor import of soda was restricted to the production of high quality vessels and panes.

2. Shapes (I. Krueger)

Glass of early medieval production in Central Europe is a vast and very complex subject, so in this short paper I can only summarise a few facts and give some examples to illustrate general remarks. As sketchy as my text is the selection of publications I can mention (see bibliography). I try to indicate mainly recent books and articles which include numerous quotations of former literature.

First fact, as has been shown in Part I on compositions: after many centuries of a fairly constant composition of “Roman” soda lime glass for most objects there is in Carolingian and Ottonian times an amazing variety of glass compositions to be found within the same area of Central Europe: soda lime glass (made with mineral soda), soda ash glass (made with soda from saline plants), an early version of wood-ash glass, high-lead glass

Woodash Glass of Early Medieval Age

(Europe)

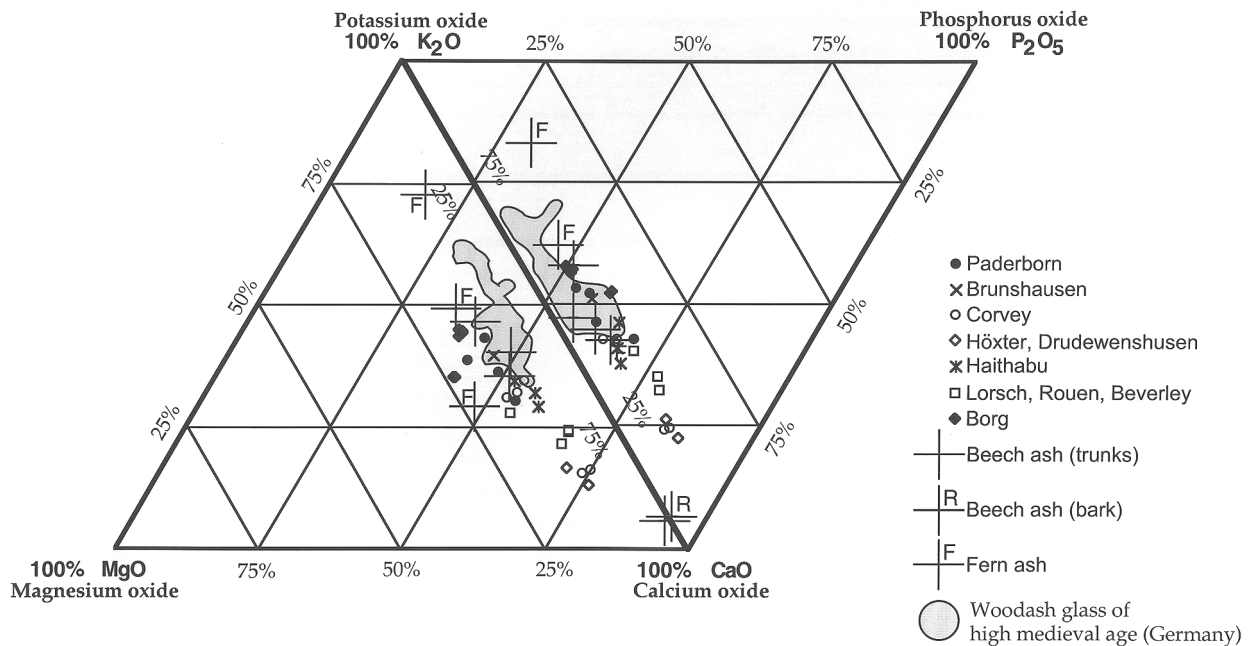


Fig. 3 — Representation of early relative to later medieval wood ash glass and terrestrial plant composition. The diagram is based on the compounds K_2O , CaO , MgO and P_2O_5 from chemical analyses. The respective elements are specific for classification. The two triangles forming the diagram are constructed from an extrapolation of the analytical data for individual samples or sample averages within two groups: $K_2O + CaO + MgO = 100\%$; $K_2O + CaO + P_2O_5 = 100\%$. Data on early medieval wood-ash glass from different sites are from the following authors: Paderborn, Brunshausen, Corvey, Höxter, Drudewenshusen: Wedepohl 1998; Haithabu: Wedepohl 2001; Lorsch: Geilmann 1955; Rouen: Barrera, Velde 1989; Beverley: Henderson 1993 and Borg: Henderson, Holand 1992. Data on later medieval glass (grey areas based on 37 plots) are from Wedepohl 1998.

(without alkali) as well as mixtures of every sort: soda lime + wood-ash, wood-ash + lead, soda lime + lead and so on.

Second fact: though glass finds from 8th to 10th centuries in Central Europe are still comparatively scarce, consisting mostly of small or tiny fragments or pieces in a very bad state of preservation, there is evidence that glass was used widely and for many different objects (some of them very refined, aesthetically as well as technically). Most frequent were small ornaments as beads, rings, enamels, false gem stones. Besides there were other small items as for example playing pieces, glass mirrors or the so-called linen smoothers. Then there was glass in architectural context reserved to high status buildings, of course: glass tesserae in mosaics, glass tiles in wall- or floor decorations and window glass of various kinds. Last but not least there were the glass vessels, mostly drinking vessels, but lamps and bowls and bottles etc. as well. These vessels were often very colourful and could be decorated in many different ways.

2.1 Paderborn

Examples to illustrate general remarks I pick mainly from three places which were mentioned in part I: Paderborn, Lorsch, and Haithabu. The area of Charlemagne's palace at Paderborn offers a good range of finds from the relevant period (Wedepohl, Winkelmann, Hartmann 1997; Gai 1999). There are many remains of glass working, including furnace parts. The numerous tesserae found here were evidently part of the raw material for this glass working (with soda lime glass), they are not as colourful as in many other places, for example at Ribe (*Karolingerzeit* 1999, Vol. 1, no. VI.84) where they represent the raw glass for bead-making. We know from written sources that there were mosaics (on walls and floors) in some Carolingian palaces and churches. Most probably Charlemagne's palace church at Aachen was adorned with mosaics from the beginning, but unfortunately the heaps of tesserae collected there cannot be exactly dated (Wehling 1995, p. 19-23, 140; *Krönungen* 2000, Vol. 1, no. 2.9). An early 9th century mosaic is still *in situ* in the church of Germigny-des-Prés (Meyvaert 2001). Mosaics are documented and testified by archaeological finds for the archbishop's palace at Liège (Evison 1988)

— tesserae of various colours “ appartenant sans doute au premier palais épiscopal liégeois, érigé par Saint Hubert au milieu du VIII^e siècle ” are exhibited in the Musée Curtius, Liège — and so on. Parts of all the tesserae which were traded for re-melting or for decorating walls and floors may have been antique pieces, as suggested by Theophilus and other sources, but the majority would have been produced in contemporary specialised workshops, but where ?

Window glass fragments from Paderborn are numerous and of different kinds. The greatest part is plain green, occasionally with red streaks, mostly badly corroded, made of wood-ash glass (*Karolingerzeit* 1999, Vol. 1, no. III.63). There are also small pieces in different colours, made of soda lime glass (*ibid.*, no. III.66) and one little fragment shows remains of a painted scroll (*ibid.*, no. III.65.) rather similar to ones on pieces from the Carolingian predecessor of the Cathedral in Cologne and from the Fraumünster at Zürich, for example (Rode 1974; Gutscher 1984; for a summary of the present state of knowledge see Becksmann 1998-99). These unspectacular small fragments can at least remind us that the technique of painting on flat glass was already in use in Carolingian times. Remains of painted window glass from this time have been found at several other sites, including for example the interesting fragments with inscription rests from Rouen (*Karolingerzeit* 1999, Vol. 1, no. III.93).

Vessel glass fragments from Paderborn present many of the shapes and decorations which are typical of this period — only reticella decoration seems to be missing, and they also present different sorts of glass compositions. Remains of funnel beakers, the most common form, were found both of wood-ash and of soda lime glass. At least one of the badly corroded wood-ash pieces seems to have had red streaks (*Karolingerzeit* 1999, Vol. 1, no. III.67). Small rim fragments indicate that others — of soda lime glass — had broad coloured rims, as known from grave finds from Birka (*Phönix* 1988, nos. 2, 15) and from many other places. Mould blown decoration, as on the famous “Traubenbecher” from Birka (*Karolingerzeit* 1999, Vol. 1, no. III.74), is found on two honey coloured fragments (*Phönix* 1988, no. 33; *Karolingerzeit* 1999, Vol. 1, no. 69) and even the rather sophisticated decoration with thin gold (or other metal) applications arranged in patterns of triangles or rhombuses is present on a rim fragment of soda lime glass (*Phönix* 1988, no. 7; *Karolingerzeit* 1999, Vol. 1, nos. III.71). Such ornaments are meanwhile known from many sites, they occur on blue, greenish or brown-yellow glass (*Phönix* 1988, p. 65-68 ; Evison 1988 ; *id.* 2000, p. 85). The triangle or rhombic pattern links these glasses to the so-called Tating ware, luxurious pottery with tin-applications (Evison 1988, p. 217 ; *Karolingerzeit* 1999, Vol. 1, nos. III.34-42), and also to the “ pseudo-cameos ” (Ypey 1962-63, p. 118, 139-141). Important in spite of their sadly weathered condition are fragments of wood-ash beakers with applied trails, some of them pro-

bably from a more or less cylindrical beaker (*Karolingerzeit* 1999, Vol. 1, no. III.68). Comparable beakers, mostly with more bulging bodies, were found in several places, for example in Birka (Arbmann 1937, pl. 9) and in Saint-Denis (*À travers le verre* 1989, no. 61). They look rather unattractive since they have lost their colour and transparency but I warn against underrating them, as well as their number and their original “beauty”. There would have been many more than can be traced since they tend to dissolve in the soil, and they would have been bright, glossy and transparent when they were new, sometimes even rather colourful as for example the famous horn from a grave at Vendeuil-Caply (Evison 1990 ; Heyworth 1990 ; Evison 2000, p. 83) which was originally green with a red spiral trail, or a beaker from Saint-Denis which had a transparent yellow trail (in the usual loops) on a green body (unpublished, mentioned in *À travers le verre* 1989, within the text for no. 61).

2.2. Lorsch

Another site mentioned in Part I was Lorsch, a very important Benedictine abbey whose church was consecrated in 774 in presence of Charlemagne. Little is left nowadays of this abbey except the famous “King’s Hall” with its memorable pattern of red and white tiles on the outside. During excavations in the 1930s important fragments of stained glass were found there (today in the museum of Darmstadt). Most impressive among them is a monumental head of a saint (Becksmann 1998-99 with older literature). During new excavations in 1999 archaeologists found sealed under a 12th century latrine building an undisturbed layer with plenty of small finds, probably mainly from the late 8th century, including many glass fragments. Though this material looks modest and unspectacular, it is fairly interesting (Müller, Sanke 2000 ; Sanke, Wedepohl, Kronz [forthcoming]). Again evidence points to glass working, there are little lumps of raw glass, tesserae, and probably moiles. There are also many pieces of window glass, plain green and coloured ones, and many fragments of simple glass vessels. These are decorated only by self-coloured threads or ribs or (on a funnel beaker fragment) red streaks. The more luxurious decorations like reticella or coloured rims etc. seem to be missing, but of course we can not expect to find the full range of glassware on a small area of c. 6 m². Little handles which may have belonged to a type of lamp we know from San Vincenzo al Volturno are unusual items within the Carolingian glass material of our regions (Stevenson 1997, p. 133). Analyses of part of the glass finds (as mentioned in Part I) show that there was soda lime glass besides the early type of wood-ash glass and then a whole range of mixtures of both types: this indicates a sort of “potluck glass working” here, using imported raw glass + recycled glass (cullet).

2.3. Haithabu

Haithabu, the third site from where I pick my examples was from about 800 to about 1050 one of the most important centres of trade and crafts, similar to Dorestad, Birka, Stara Ladoga and some others. Accordingly, the many thousands of glass finds from Haithabu (Steppuhn 1998) are very differently accentuated than those from palaces and monasteries. Besides the many fragments of raw glass (of different composition and in various forms) and other debris indicating glass working in this settlement, the products which were used, traded, and partly made there consist mainly of beads; there were found beads of every form, colour, decoration and glass composition. Parts of them were evidently imported and others were made in Haithabu, among them soda ash pieces and such in high lead glass (mainly green, a few yellow). So-called linen smoothers are represented by as many as 103 pieces — whole specimens or fragments — which were found all over the settlement. This is not the place to summarise all the arguments of the ongoing discussion about their primary function: tools for textile working (“linen smoothers”) or rawglass cakes? (Schmaedecke 1998 ; Steppuhn 1999 ; Foy 2000, p. 155-159). Here I will just report the recently established fact that most of them seem to be made of wood-ash glass and some of them of a special silica-lime-lead glass. This very special sort of lead containing glass has been detected in linen smoothers from several sites within France as well as from Haithabu, York, and Novgorod, and that would indicate long distance trade for these objects. But it seems that they were

not traded as ingots, since this special sort of lead glass is restricted to these linen smoothers and has so far never been found used for other glass objects. The results of an international research project on this subject will be presented at an archaeometry meeting in Amsterdam 2002 by B. Gratuze, K.H. Wedepohl, J. Bayley, F. Tereygeol, J. Lancelot and D. Foy (see already in this volume Gratuze *et al.*). Window glass fragments are remarkably rare at Haithabu, just 25 pieces (none of them analysed). Most of the fragments of glass vessels are too small to give a clear idea of the shape, with the exception of the narrow parts of funnel beakers (Steppuhn 1998, p. 59-60). But they show the familiar range of decorations, including coloured rims, reticella, one mould blown “Traubenbecher” (Steppuhn 1998, p. 61). Remarkable are some fragments, probably from several vessels, of transparent blue glass with opaque white decoration (*Phönix* 1988, no. 27 ; Steppuhn 1998, p. 61-62). A small series of similar pieces has been found in Germany, Switzerland, Austria, and France. The famous barrel-shaped beaker from Saint-Savin at Poitiers which miraculously survived intact — hidden in an altar — may be included in this group, though the prunts in its decoration do not occur on the other pieces (Simon-Hiernard 2001). To judge from the contexts these glasses are hardly older than 11th century, and it is still quite open where they were made — which might be the headline for this entire sketch.

Bibliography

- À travers le verre 1989, Foy (D.), Sennequier (G.) eds, *À travers le verre, du Moyen Âge à la Renaissance, Exhibition Catalogue, Rouen 1989*, Nancy, 1989.
- Andréossy (A.F.) 1823, *Mémoire sur la vallée des lacs natroun et celle du Fleuve sans eau, d'après la reconnaissance faite les 4, 5, 6, 7 et 8 pluviôse, An VII (23-27 janvier 1799)*, *Description de l'Égypte, État moderne XII*, Paris, 1823, p. 1-40.
- Arbmann (H.) 1937, *Schweden und das karolingische Reich*, Stockholm, 1937.
- Barrera (J.), Velde (B.) 1989, “A study of French medieval glass compositions”, *JGS* 31, 1989, p. 48-54.
- Bayley (J.) 1990, “Glass rings and the manufacture of high-lead glass”, in Biddle (M.) ed., *Objects and economy in medieval Winchester, Winchester Studies 7*, Winchester, 1990, p. 268-269.
- Becksmann (R.) 1998-99, “Vor- und frühromanische Glasmalerei in Deutschland. Quellen – Funde – Hypothesen”, *Zeitschrift des deutschen Vereins für Kunstwissenschaft* 52/53, 1998-99, p. 197-211.
- Bezborodov (M.A.) 1975, *Chemie und Technologie der antiken und mittelalterlichen Gläser*, Mainz, 1975.
- Brill (R.H.) 1999, *Chemical Analyses of Early Glass*, Corning NY, 1999.
- Dekowna (M.) 1990, “Untersuchungen an Glasfunden aus Haithabu”, *Berichte über die Ausgrabungen in Haithabu, Bericht 27. Das archäologische Fundmaterial V*, Neumünster, 1990.
- Evison (V.I.) 1988, “Vieux-Marché, Place Saint-Lambert, Liège – The Glass”, in Otte (M.) ed., *Les fouilles de la Place Saint-Lambert à Liège 2. Le vieux marché, Études et recherches archéologiques de l'Université de Liège* 23, Liège, 1988, p. 215-219.

- Evison (V.I.) 1990, " The Vendeuil-Caply glass horn ", *Nord-Ouest Archéologie* 3, 1990, p. 89-96.
- Evison (V.I.) 2000, " Glass vessels in England, AD 400-1100 ", in Price (J.) ed., *Glass in Britain and Ireland AD 350-1100, British Museum Occasional Papers 127*, London, 2000, p. 47-104.
- Foy (D.) 2000, " Technologie, géographie, économie. Les ateliers de verriers primaires et secondaires en Occident. Esquisse d'une évolution de l'Antiquité au Moyen Âge ", in Nenna (M.-D.) ed., *La route du verre: ateliers primaires et secondaires de verriers du second millénaire av. J.-C. au Moyen Âge (Lyon, 1997), Travaux de la Maison de l'Orient méditerranéen* 33, Lyon, 2000, p. 147-170.
- Freestone (I.C.), Bimson (M.) 1996, " Appendix : The enamel " in Mitchell (J.) ed., *San Vincenzo al Volturno 3; The finds from the 1980-1986 excavations*, 1996.
- Freestone (I.C.), Gorin-Rosen (Y.) 1999, " The great glass slab at Bet She'arim, Israel: an early islamic glassmaking experiment ? ", *JGS* 41, 1999, p. 105-116.
- Freestone (I.C.), Hughes (M.J.), Stapleton (C.P.) 1999, " Compositional studies of some Saxon glass ", *Current Research on the History of Glass through Scientific Analysis*, 29th March 1999.
- Gai (S.) 1999, " Karolingische Glasfunde der Pfalz Paderborn ", in *Karolingerzeit* 1999, Vol. 3, p. 212-217.
- Gaitzch (W.), Follmann-Schulz (A.B.), Wedepohl (K.H.), Hartman (G.), Tegtmeier (U.) 2002, " Spätromische Glashütten im Hambacher Forst westlich von Köln. Der Produktionsort der ECVA-Fasskrüge. Archäologische und naturwissenschaftliche Untersuchungen ", *Bonner Jahrbücher* 2002 forthcoming.
- Geilmann (W.) 1955, " Beiträge zur Kenntnis alter Gläser III: die chemische Zusammensetzung einiger alter Gläser des 10. bis 18. Jahrhunderts ", *Glastechnische Berichte* 28, 1955, p. 146-156.
- Gratuze (B.), Barrandon (J.-N.) 1990, " Islamic glass weights and stamps: analysis using nuclear techniques ", *Archaeometry* 32, 1990, p. 155-162.
- Gutscher (D.) 1984, " Karolingische Holzbauten im Norden der Fraumünsterabtei ", *Zeitschrift für Schweizerische Archäologie und Kunstgeschichte* 41, 1984, p. 207-224.
- Henderson (J.) 1993, " Aspects of early medieval glass production in Britain ", *Annales AIHV 12 (Vienne 1991)*, Lochem, 1993, p. 247-259.
- Henderson (J.), Holand (I.) 1992, " The glass from Borg, an early medieval chieftain's farm in northern Norway ", *Medieval Archaeology* 36, 1992, p. 29-58.
- Heyworth (M.) 1990, " Analysis of glass vessel fragments from Vendeuil, France ", *Nord-Ouest Archéologie* 3, 1990, p. 97-98.
- Karolingerzeit* 1999, 799. *Kunst und Kultur der Karolingerzeit, Exhibition Catalogue, Paderborn 1999*, Mainz, 1999.
- Krönungen* 2000, *Krönungen. Könige in Aachen – Geschichte und Mythos, Exhibition Catalogue, Aachen 2000*, Mainz, 2000.
- Meyvaert (P.) 2001, " Maximilien Théodore Chrétien and the Apse Mosaic at Germigny-des-Prés ", *Gazette des Beaux-Arts* 137, 2001, p. 203-220.
- Müller (J.), Sanke (M.) 2000, " Neue Ausgrabungen im ehemaligen Reichskloster Lorsch 1998-2000 ", *Denkmalpflege & Kulturgeschichte* 2000/2, p. 23-27.
- Phönix* 1988, Baumgartner (E.), Krueger (I.), *Phönix aus Sand und Asche. Glas des Mittelalters, Exhibition Catalogue, Bonn Basel 1988*, München, 1988.
- Rode (H.) 1974, " Eine Ornamentscherbe aus der Kölner Domgrabung und Erwägungen zu den Glasfenstern des Alten Doms ", *Beiträge zur Rheinischen Kunstgeschichte und Denkmalpflege II*, Düsseldorf, 1974, p. 15-33.
- Sanke (M.), Wedepohl (K. H.), Kronz (A.) 2002, " Karolingisches Glas aus dem Kloster Lorsch ", *Zeitschrift für Archäologie des Mittelalters* 2002 (forthcoming).
- Schmaedecke (M.) 1998, " Glasbarren oder Glättstein? Beobachtungen zur mittelalterlichen Glasherstellung und Glasverarbeitung ", *Beiträge zur Archäologie des Mittelalters 1998, Archäologie und Museum Heft 37*, Liestal, 1998, p. 93-120.
- Simon-Hiernard (D.) 2001, " Le vase de Saint-Savin: un exceptionnel verre médiéval au musée Sainte-Croix de Poitiers ", *Revue du Louvre* 2001/1, p. 68-75.
- Stephan (H.G.), Wedepohl (K.H.), Hartmann (G.) 1997, " Mittelalterliches Glas aus dem Reichskloster Corvey. Mit einem Nachtrag zu den Analyseergebnissen von Gläsern aus dem Kloster Brunshausen ", *Germania* 75, 1997, p. 673-715.
- Stappuhn (P.) 1998, " Glasfunde des 8.-13. Jahrhunderts in Siedlungen. Veränderungen vom frühen zum späten Mittelalter, dargestellt am Beispiel Haithabu/Schleswig ", in Wesse (A.) ed., *Studien zur Archäologie des Ostseeraumes von der Eisenzeit zum Mittelalter*, Neumünster, 1998, p. 461-467.
- Stappuhn (P.) 1999, " Der mittelalterliche Gniedelstein : Glättglas oder Glasbarren? Zu Primärfunktion und Kontinuität eines Glasobjektes vom Frühmittelalter bis zur Neuzeit ", *Nachrichten aus Niedersachsens Urgeschichte* 68, 1999, p. 113-139.
- Stevenson (J.) 1997, " Ninth century glassware production at San Vincenzo al Volturno, Italy: some new evidence from recent excavations ", *Material culture in Medieval Europe – Papers of the 'Medieval Europe Brugge 1997' Conference*, Zellik, 1997, Vol. 7, p. 125-136.

- Wedepohl (K.H.) 1998, “ Mittelalterliches Glas in Mitteleuropa: Zusammensetzung, Herstellung, Rohstoffe ”, *Nachrichten der Akademie der Wissenschaften Göttingen, Mathematisch-Physikalische Klasse*, 1998/1, p. 1-56.
- Wedepohl (K.H.) 2001, “ The composition of glass from the Carolingian and post-Carolingian period in Central Europe ”, in Dell’Acqua (F.), Silva (R.) eds., *Il colore nel Medioevo, arte, simbolo, tecnica: la vetrata in Occidente dal IV al XI secolo*, Lucca, 2001, p. 257-270.
- Wedepohl (K.H.), Pirling (R.), Hartmann (G.) 1997, “ Glasgefäße römischer und fränkischer Herstellung vom Friedhof Krefeld-Gellep ”, *Bonner Jahrbücher* 197, 1997, p. 177-189.
- Wedepohl (K.H.), Winkelmann (W.), Hartmann (G.) 1997, “ Glasfunde aus der karolingischen Pfalz in Paderborn und die frühe Holzasche-Glasherstellung ”, *Ausgrabungen und Funde in Westfalen-Lippe* 9A, Münster, 1997, p. 41-53.
- Wehling (U.) 1995, *Die Mosaiken im Aachener Münster und ihre Vorstufen, Arbeitshefte der rheinischen Denkmalpflege* 46, Köln, 1995.
- Ypey (J.) 1962-63, “ Die Funde aus dem frühmittelalterlichen Gräberfeld Huinerveld bei Putten im Museum Nairac in Barnefeld ”, *Bericht van de rijksdienst voor het oudheidskundig bodemonderzoek* 12/13, 1962-63, p. 99-152.