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EARLY MEDIEVAL GLASS FINDS FROM THE NORTH FRISIAN ISLANDS (GERMANY) – EVIDENCE FOR THE IMPORT OF VESSEL GLASS AND LOCAL BEAD PRODUCTION

The North Frisian Islands, located along the northernmost part of the German North Sea coast, were part of the early medieval Frisian settlement area and an important station in the North Sea trade network. The islands of Föhr, Amrum and Sylt were therefore a major focus area for the investigation of 7th-11th century trade settlements, conducted by the North Sea Harbour Project during the years of 2013-2018. The Project, located at the Lower Saxony Institute for historical coastal Research, was part of the German Research Foundation's Priority Programme 1630 »Harbours from the Roman Period to the Middle Ages«. Geophysical Prospections and subsequent archaeological excavations uncovered several large trade settlements on the island of Föhr at Witsum, Nieblum and Goting, yielding a rich spectrum of import related goods, including a remarkable number of glass objects [1] (**fig. 1**). While glass objects, namely vessel glass and beads, were already known to occur in early medieval graves on the North Frisian Islands, there are only two other settlements with vessel glass. Excavations and find collection by the State Archaeological Department of Schleswig-Holstein had previously uncovered two settlement sites at Tinnum and Wenningstedt on the island of Sylt, which also possess a large number of glass objects [2]. These recent findings indicated the unexpected magnitude of glass objects in the early medieval North Frisian trade and the possibilities for research into the islands' trade connections and local consumption. The North Sea Harbour Project was thus invited by M. Dodt and A. Kronz to join in the programme of chemical glass analysis conducted by the Project »The early Medieval Harbour of Cologne – Place of Production and export of glass«.

41 glass objects from the North Frisian trade settlements were chosen for chemical analysis in order to answer research questions raised by both projects: Where did the North Frisian glass objects originate and is there a trade connection between the glass production centres at Cologne as well as in the Rhineland and the North Sea coastal areas? Which kind of glass was used? Was vessel glass recycled for a local glass bead production?

This paper aims to provide an overview on the North Frisian sites with finds of vessel glass, the analysed find material and the conclusions drawn from the chemical analysis [3].

STATE OF KNOWLEDGE ON NORTH FRISIAN GLASS FINDS

The North Frisian Islands possess a rich archaeological heritage of the first millennium AD with a long research tradition. During the late 19th and the first part of the 20th century, research amateurs and archaeologists documented many finds from settlements and burials, which became known due to intensified agriculture and construction works. By the mid-20th century, most of the large urn cemeteries and burial mounds have been entirely excavated and contributed to a large range of archaeological find records [4].

Glass items form a rare class of find objects in the North Frisian material. During the Roman Iron Age and Migration Period, the only known settlement site with vessel glass is the beach market site at Norddorf, is-

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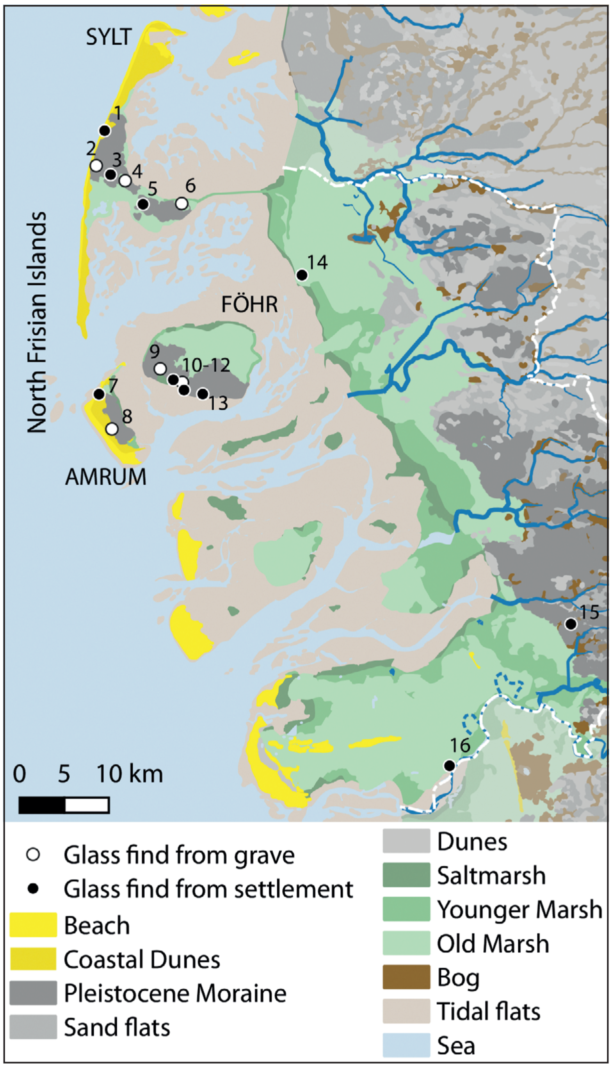


Fig. 1 Map of North Frisia with archaeological sites mentioned in the text: Island of Sylt: **1** Wenningstedt. – **2** Westerland. – **3** Tinnum. – **4** Keitum. – **5** Archsum. – **6** Morsum. – Island of Amrum: **7** Norddorf. – **8** Nebel. – Island of Föhr: **9** Hedehusum/Süderende. – **10** Witsum. – **11-12** Goting. – **13** Nieblum. – Mainland: **14** Emmelsbüll-Toftum. – **15** Rantrum. – **16** Elisenhof. – (Map B. Majchczack; Map data GÜK200 ©Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, 2007).

land of Amrum, which is discussed by Segschneider in this volume [5]. Mostly in the 4th and 5th century, a seasonal market was held at the beach harbour and numerous pieces of vessel glass, including bowls, Kempston type beakers and claw beakers were imported alongside a large number of colourful glass beads [6]. The Norddorf site might be regarded as an entrepôt to the North Frisian Islands, but none of the imported glass vessels turned up on other settlement sites on the islands. Only one vessel sherd was found in a cremation grave in Nebel, also island of Amrum [7]. However, sherds of vessel glass were found further westwards in settlements at Emmelsbüll-Toftum on the former marsh island Wiedingharde [8] and at Rantrum on the southern mainland [9]. The glass beads, however, are by far more common in urn cremations on the islands, reflecting their obviously huge numbers in imports. The Migration Period habitation ends around the end of the fifth or the first quarter of the 6th century. After a hiatus of approximately 150 years, the early medieval resettlement of North Frisia begins in the mid-7th century [10].

During the Early Medieval Period up to the mid-9th century, cremation graves with urns, set in small burial mounds, are the predominant habit of burial on the North Frisian Islands. The mounds cluster in cemeteries of up to 120 burial mounds, which have largely been excavated [11]. On the island of Sylt, pieces of a molten vessel of light green glass were found at Keitum [12] and pieces of a light green funnel beaker at Morsum [13]. Further pieces of light green funnel beakers were found in urn graves on the island of Föhr at Süderende [14] and Goting [15]. The most spectacular burial find comes from Westerland, island of Sylt. Already excavated in 1766, a burial mound reportedly contained two entire glass vessels, of which one is preserved (**fig. 2**). It is a cylindrical beaker of dark blue glass in superb condition, decorated with thin yellow trails on the neck and shoulder and two rows of a criss-cross pattern of blue trails with yellow dots [16]. This unique piece is possibly of Anglo-Saxon production and dated to the late 7th or early 8th century [17].

For a long time, settlement finds of vessel glass were only known from the large-scale excavations at Elisenhof at the Eider estuary in southern North Frisia [18] and they were unknown from any settlement sites on the North Frisian Islands. This was due to the very limited number of excavations and probably to the excavation techniques, which did not include water sieving. The excavations at the trade settlements at Tinnum, island of Sylt since 2002, surface finds from Wenningstedt and one sherd from an excavation in

Archsum[19] as well as the settlement prospections and excavations at Nieblum, Goting and Witsum on the island of Föhr changed this picture completely. The numerous finds of vessel glass and beads prove a strong influx of glass objects during the 7th to 9th century and provide a broad basis for material studies. A variety of samples was selected for chemical analysis, which shall be discussed in this paper.

Fig. 2 Westerland, island of Sylt. Intact cylindrical beaker of blue glass with polychrome decoration, late 7th-8th century AD. Object number 7723. – (Photo L. Larsen, Danish National Museum, CC-BY-SA).

EARLY MEDIEVAL TRADING SITES WITH GLASS FINDS ON THE NORTH FRISIAN ISLANDS

During the Early Medieval Period between the 7th and 11th century, the islands of Föhr, Amrum and Sylt formed the most important and densely settled part of the North Frisian region. Surrounded by a maritime landscape of marshes, bogs, mudflats and sand spits, the elevated moraine cores of these three islands offered a favourable settlement ground, with easy access to fertile marshlands and tidal creeks, leading to the open sea. On the island of Föhr, the early medieval settlements at Witsum, Nieblum and Goting are situated along the southern coast of the island, located on the high moraine core in close proximity to the lower marshlands or beaches as well as nearby tidal creeks and wetlands[20]. Similarly, on the island of Sylt, the settlement of Tinnum is located on a small moraine, close to a tidal creek crossing the marshlands[21]. The settlement at Wenningstedt is located on the high moraine, close to the cliffs and beaches. All settlements seem to start around the mid- or late 7th century in the course of a (probably Frisian) migration.

Tinnum, island of Sylt (Sylt-Ost Tinnum NF, LA 128)

In the years from 2002 to 2012, the State Archaeological Department of Schleswig-Holstein conducted several rescue excavations in the area of a new built commercial park in the village of Tinnum, island of Sylt[22]. The settlement traces stretch over several hectares and date into different phases of the entire first millennium AD. The north-eastern part of the area contained an early medieval settlement with traces of mainly pit houses, pits and wells. The absence of yard enclosures, ditches or any above ground structures like longhouses indicate a seasonal character of the settlement[23]. Numerous finds of tools for textile production, smithing slags, several thousand pieces of debris from amber working and many shards of vessel glass alongside broken glass beads indicate a focus on craft production, marking the settlement a possible trading site or seasonal marketplace. The find material, namely the shards of local pottery as well as the glass objects, date the settlement into the 7th to 10th century. The glass objects from Tinnum were

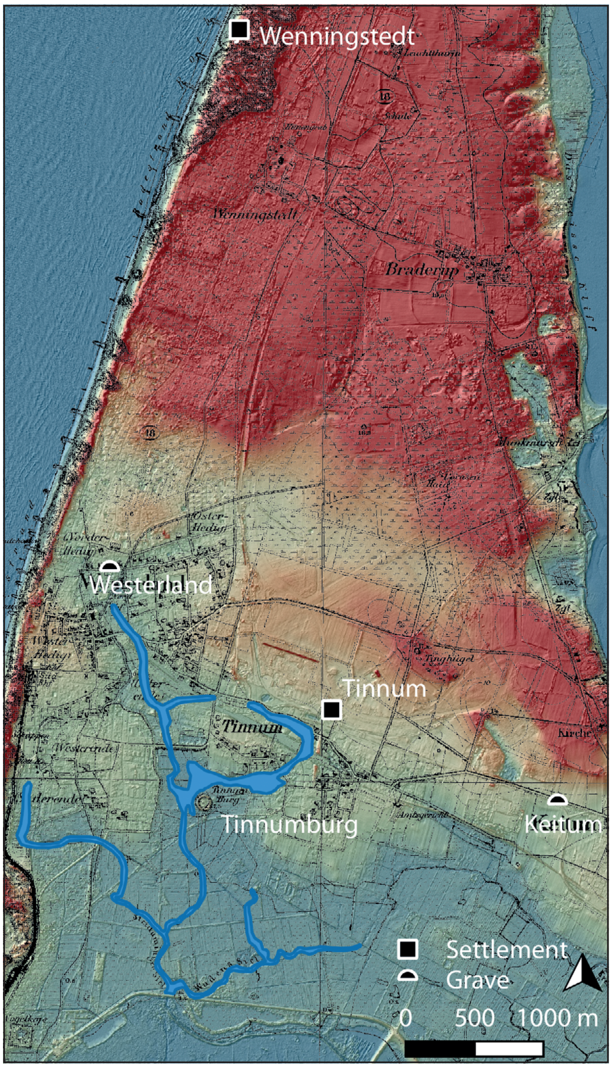


Fig. 3 Island of Sylt. Central part of the island with early medieval sites with glass finds, possibly navigable waterways (blue, reconstruction based on historical maps and relief anomalies from Lidar-data) and the Tinnumburg ring fortress. – (Map B. Majchczack; Base map Prussian Map of 1879 and DGM2, ©GeoBasis-DE/LVermGeo SH).

mostly found by water sieving within the fillings of the pit house features and parts of an adjacent cultural layer. They comprise sherds of glass vessels and glass beads, one rod-end and one piece of molten glass.

A ring fortress protects the access to the trading site. The Tinnumburg lies on the foot of the moraine core, surrounded by marsh and wetlands. A tidal creek (**fig. 3**) connects the ring fortress with the open sea to the south, while a small arm of the wetland, possibly navigable by small boats, leads towards the trading site [24].

The vessel sherds share several characteristics: The glass quality is very high with mostly transparent glass including small bubbles and a very good state of preservation. This led to the assumption of the sherds to be of a high-quality soda-lime glass. The vessels are highly fragmented with small sherd sizes of usually less than 2 cm. There are wall sherds only, no rims. This makes an identification of the vessel types difficult. The diameters of the vessels indicate them to include large palm cups and globular beakers. A sherd of a thin, tubular shape possibly derived from a drinking horn or, more likely, a claw beaker. The colours of the glass vessels are remarkable. While a proportion is of a common light blue-green colour, more vibrant colours dominate the range with darker blue-green, vivid green-blue and vivid to dark turquoise glass colours. These vibrantly coloured sherds find their exact matches in the glass bead material, indicating a direct recycling of vessel sherds by a local beadmaker. Besides the blue coloured ones, beads in opaque yellow, dark red and light to dark green were found, which show no resemblance to the vessel glass. These beads might have been produced from tesserae (notably, none were found in the excavations) or from recycled vessel glass with added colourants and opacifiers.

The typological dating of the Tinnum beads is difficult to establish, since characteristic forms and decorations are missing. A dating into the 7th/8th century is most likely due to the general forms of the beads and the other associated find material. It is striking, that several typical features of 8th century beads are missing in Tinnum: dark blue glass (with Co as colourant) and white-red polychrome decorations, as they become common in South Scandinavian bead making around AD 725, are completely missing. Also, the later black or blue beads with yellow trails (»wasp beads«) or the mass-imported cut-drawn beads starting in the late 8th century are completely absent in Tinnum [25]. It can therefore be argued, that the Tinnum bead material is most likely to be dated into the last decades of the 7th or the early 8th century [26].

All analysed glass objects were found in a particular area of the Tinnum settlement, distributed over several pit houses and a cultural layer. The find material in this area is lacking objects with a distinct and clearly datable typology, making it difficult to establish a precise dating for the pit houses and the overall settlement area. However, the glass vessel typology with bowls and globular beakers, the absence of funnel beakers and the absence of the usually widespread polychrome beads indicate a rather early dating in the beginning North Frisian Early Middle Ages, namely into the late 7th or early 8th century. This is further backed by pottery finds and dendrochronological dates from settlement features[27].

Fig. 4 Wenningstedt, island of Sylt. Photo of the site in November 2013. The dark earth in the valley is the remaining fossil topsoil, containing finds and archaeological features. – (Photo B. Majchczack).

The chemical analysis and thus the selection of sampled objects aim to find a chemical connection between the vessel glass and the optically similar glass beads to prove a local bead making workshop, as well as to find clues to the provenance of the glass vessels and their dating.

Wenningstedt, island of Sylt (Wenningstedt NF, LA 149)

The archaeological site of Wenningstedt is a small area in the dune belt on the western coast of the island of Sylt on the edge of the »Red Cliff«. The narrow dune valley has a size of approx. 160 m × 30 m only (**fig. 4**). First finds occurred in 2007, when wind erosion enlarged the valley and reached the fossil topsoil[28]. The erosion exposed archaeological features like ditches and pit houses as well as finds. Recurrent field surveys collected early medieval objects including pottery sherds, a glass vessel sherd, numerous glass beads, pieces of amber and a sceat coin. All finds date into the 8th century. The finds and archaeological features strongly indicate that the find spot in the valley is part of a probably much larger trading site with a similar structure as Tinnum or Witsum.

The glass finds comprise one sherd of a funnel beaker and numerous glass beads. The beads belong to the distinctive group of blue-white-red beads of the mid-8th century[29]. All beads are intact and no production waste or other evidence for a local bead production was found.

Nieblum, island of Föhr (Nieblum NF, LA 67)

Close to the southern coast of Föhr near the beaches of Nieblum lies a remarkable early medieval settlement site (**fig. 5**). Following the first discovery in summer of 2006 by aerial pictures, subsequent geomagnetic prospections and field surveys[30], a first trial excavation took place in 2016. The settlement stretches over an area of approx. 480 m × 200 m in total. A system of multiple ditches or moats forms an oval-shaped enclosure for the settlement. The interior seems to be divided by yard enclosures and contains mostly pit houses as seen in the crop marks; other types of buildings are likely but not detectable. The find material from field surveys include early medieval pottery, a whetstone and traces of iron smithing. The excavation of 2016[31] focused at three pit houses and parts of the enclosure, proving them to date into the 8th-9th century. One of the pit

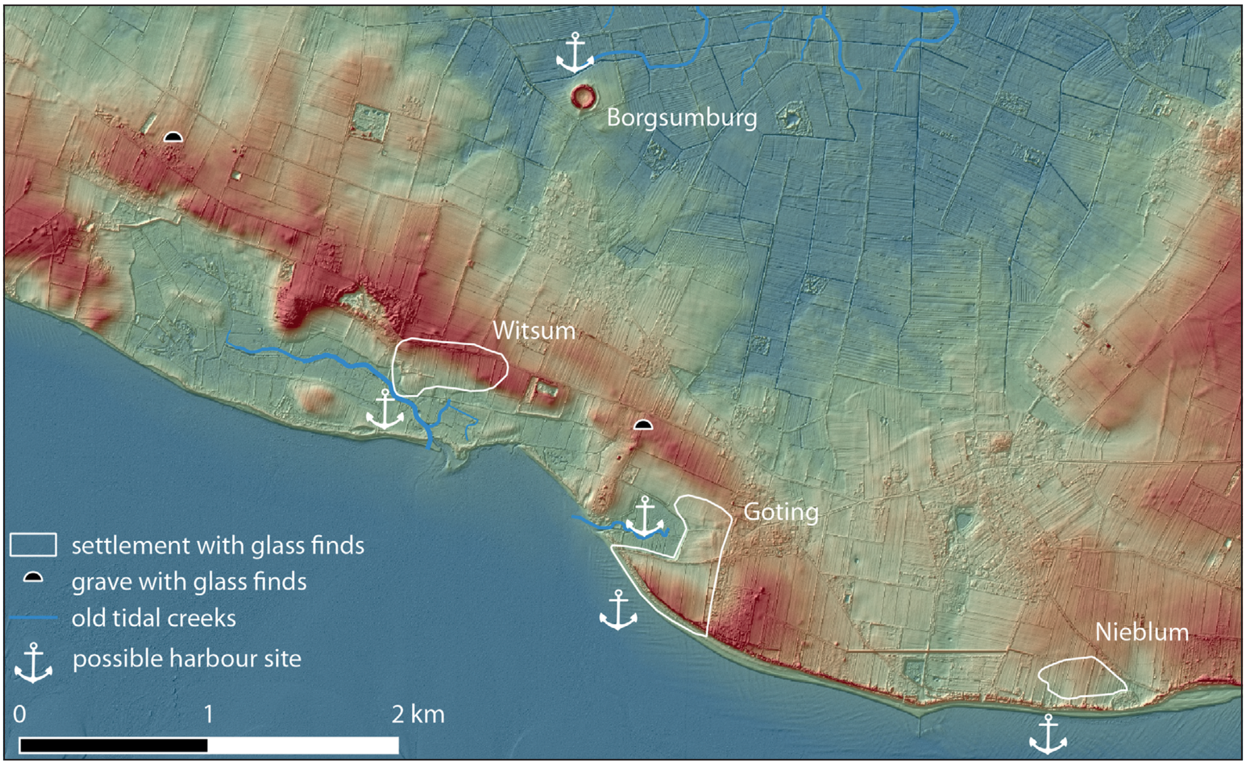


Fig. 5 Island of Föhr. Southern coast of the island with early medieval sites with glass finds, possibly navigable waterways (reconstruction based on historical maps and relief anomalies from Lidar-data), possible harbour sites and the Borgsumburg ring fortress. – (Map B. Majchczack; Base map: Prussian Map of 1879 and DGM2, ©GeoBasis-DE/LVermGeo SH).

houses contained sherds of a funnel beaker and two broken glass beads alongside distinctive shell-tempered pottery of the late 8th-9th century. One of the beads is a fragment of a distinctive »wasp bead« of the late 8th century[32]. Although the excavation was very limited, it provided strong evidence that the Nieblum settlement was possibly a protected village and a centre of production for textiles, iron products and maybe glass beads.

Witsum, island of Föhr (Witsum NF, LA 146)

Just like at Nieblum, aerial photos led to the discovery of an early medieval settlement at Witsum in 2006. Located on the slope of the high moraine core and overlooking a small stretch of marshland and the beaches to the south (**fig. 5**), the settlement features a village-like system of yard enclosures and many pit houses. The small river »Godel« touches the settlement's southern edge before it flows into the North Sea, creating a natural harbour situation. The settlement measures about 510 m × 220-260 m with a total size of approx. 10 hectares. It was entirely prospected with magnetometry since 2006, detailed prospections with GPR, seismic methods and electric resistivity tomography followed. Especially the geomagnetic measurements reveal the settlement layout in detail with at least 105 pit houses, multiple phases of yard enclosures, a central road and several long houses. Field surveys and metal detecting turned up numerous finds of early medieval local pottery, loom weights, quernstone fragments and a silver coin of the 11th century. These indications for craft production and imported goods as well as the easy access to the open sea put the research focus on Witsum as a possible trading site[33]. The North Sea Harbour Project conducted eleven weeks of excavation at Witsum during 2013-2016, opening trenches in different areas of the settlement to gain an overall insight into the settlement structures, gather dating find material and look for evidence of craft production and economic activities[34].

In the excavation of 2016, four pit houses were fully excavated under careful water sieving of their fillings. Besides evidence for textile production and amber bead making, all of them contained glass objects in form of vessel sherds, beads, two tesserae and a possible gaming piece. The distinctive blue-white-red decoration of the beads place the objects and the pit houses in the mid-8th century[35]. The glass sherds belong to different types of vessels, namely polychrome globular beakers, polychrome funnel beakers, mould-blown funnel beakers or elongated palm cups and a claw beaker. A selection of twelve vessel sherds for chemical analysis address questions on the origin of the vessels, whether vessels were imported for local consumption or in form of cullet for bead production and the distribution of vessel sherds within the settlement. To gain information on the possible bead production from vessel sherds, three beads, one tessera and the gaming piece were also sampled.

Goting, island of Föhr (Nieblum Goting NF, LA 151)

Also located on the southern shore of Föhr and in sight of the Witsum settlement, an elevated moraine at Goting hosts another important settlement (**fig. 5**). Early medieval finds from the active cliff at Goting, including a hoard of 87 sceat coins of the 8th century found in 1977, indicated a settlement with trade activities. Furthermore, a small inland wetland with a tidal creek towards the open sea, called »Bruk«, might have acted as a secure harbour location for the adjacent settlement. A geomagnetic prospection of the entire area around the »Bruk« and the cliff revealed settlement sections with different structures. Close to the beach and on the high moraine, the settlement structure is dominated by single pit houses. A road leads towards the wetlands. Next to the wetland, the magnetometry shows a parcel-like pattern with strong anomalies, followed by single long houses and clusters of strong anomalies to the Northeast[36]. The North Sea Harbour Project excavated for 14 weeks in 2014-2018 in two different parts of the settlement. The excavations in the parcelled area east of the wetland revealed a multi-layered workshop area with phases of the 8th to 10th century and further settlement remains up to the High Middle Ages. The workshop layers contained manifold evidence of iron smithing and boat repairs but little glass except some beads. These beads cover the 8th to 10th century with typical blue-white-red beads of the mid-8th century, drawn-cut beads, a mosaic bead and metal-foiled beads of the late 8th-9th century and monochrome wound beads of the 10th century[37].

In the south-eastern area close to the cliff, three pit houses of the 8th and 9th century were excavated, all of them contained glass finds. Several sherds belonged to glass vessels, mostly funnel beakers but also the outward-folded rim of a bowl or large palm cup with yellow trailing. Three of these sherds were selected for chemical analysis. Besides the vessel sherds, several entire glass beads of regional production, but mostly imported oriental drawn-cut and metal foiled beads were found. It is possible to date the pit-houses through their bead assemblages. One pit-house contains two characteristic wasp-beads and one metal-foiled bead and may be dated into the late 8th century, while the other two pit-houses may date somewhat younger, containing only blue drawn-cut beads and metal-foiled beads[38].

CATALOGUE OF GLASS FINDS SELECTED FOR CHEMICAL ANALYSIS

The Catalogue lists all glass samples, which have been analysed and discussed in the analytical results. It is sorted by archaeological sites and features[39]. The sample number refers to the KHa series of samples taken by A. Kronz at the Electron Probe Laboratory at the Centre for Geosciences of Göttingen University, KHa stands for the Cologne Harbour Project. The inventory number designates the find object as inventoried by the Archaeological Museum Schloss Gottorf at Schleswig.

Sylt-Ost Tinnum LA 128

Pit house AU2007-607/5 – Late 7th to 8th century

KHa 140: Small wall sherd with a thin tubular form, possibly part of a drinking-horn or claw beaker. Blue-green transparent with thin dark red streaking and small bubbles. Tube diameter < 1 cm. Sherd size 9 mm × 4.6 mm. Wall thickness 2.1 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.140.
KHa 141: Small wall sherd of a palm cup or globular beaker of vivid turquoise blue transparent glass with many small bubbles. Sherd size 9.7 mm × 6 mm. Wall thickness 1.5 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.141.
KHa 143: Small wall sherd of vivid green-blue transparent glass with dark green-blue streaking and many small bubbles. Sherd size 9.2 mm × 14.2 mm. Wall thickness 1.5 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.154.
KHa 144: Wall sherd, possibly of a globular or bag beaker, of vivid turquoise blue transparent glass with many small bubbles. Significantly curved with a thin horizontal and a thick vertical trail of the same colour on the outside. Sherd size 14.9 mm × 14.8 mm. Wall thickness 1.8 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.157.
KHa 145: Small wall sherd of vivid green-blue transparent glass with small bubbles. Sherd size 7 mm × 4.1 mm. Wall thickness 1.6 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.159.
KHa 155: Wall sherd of light blue-green transparent glass with many small bubbles. Sherd size 6.2 mm × 19.3 mm. Wall thickness 1.4 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.199.

Pit house AU2007-607/65 – Late 7th to 8th century

KHa 146: Wall sherd of a large palm cup or bowl of dark turquoise blue transparent glass with many small bubbles. Three horizontal trails of the same colour. Sherd size 14.7 mm × 18 mm. Wall thickness 1.4 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.161.
KHa 147: Fragment (halve) of a monochrome biconical bead of vivid blue-green transparent glass, slightly clouded by small bubbles. Length 3.8 mm. Diameter 5.3 mm. Hole diameter 1-1.8 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.165.
KHa 148: Fragment (halve) of a monochrome melon-shaped bead of vivid turquoise blue transparent glass with many small bubbles. Length 8.5 mm. Diameter 11 mm. Hole diameter 4.5 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.166.

Pit house AU2007-607/7 – Late 7th to 8th century

KHa 114: Wall sherd of a bowl of light blue-green transparent glass with many small bubbles. Vessel diameter approx. 16 cm. Sherd size 18 mm × 20 mm. Wall thickness 1.2-1.8 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.179.
KHa 115: Small wall sherd of light blue-green transparent glass with many small bubbles. Sherd size 15 mm × 4.4 mm. Wall thickness 1.4 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.180.
KHa 142: Fragment (halve) of a monochrome ring-shaped bead of vivid yellow opaque glass. Length 6.8 mm. Diameter 9 mm. Hole diameter 4.6 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.149.
KHa 149: Sherd of colourless transparent flat glass with many small and medium sized bubbles and an uneven surface. Sherd size 18 mm × 13 mm. Wall thickness 1.8 mm. Dating: modern (due to chemical analysis, see below). Inv.-No. SH2007-607.169.
KHa 150: Lump of brownish transparent glass with white patina and uneven surface. Size 23 mm × 17 mm. Weight 2 g. Dating: possibly late 7th to 8th century. Inv.-No. SH2007-607.170.
KHa 151: Small wall sherd of a palm cup or globular beaker of vivid turquoise blue transparent glass with many small bubbles. Sherd size 9 mm × 7 mm. Wall thickness 2.5 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.172.

KHa 152: Fragment of a monochrome barrel-shaped bead of dark red opaque glass. Length 6.9 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.182.

KHa 153: Fragment (third) of a monochrome melon-shaped bead of vivid turquoise-blue transparent glass with many small bubbles. Length 7 mm. Hole diameter 4.5 mm. Dating: late 7th to 8th century. Inv.-No. SH2007-607.193.

Cultural layer in trench 1, excavation AU2007-607 – Late 7th to 8th century

KHa 154: Rod end of dark green transparent glass with many small bubbles. Size 20 × 16 × 10 mm. Weight 2 g. Dating: late 7th to 8th century. Inv.-No. SH2007-607.197.

Wenningstedt LA 149

Surface finds from eroded cultural layer, find report FM2013-704

KHa 116: Wall sherds from the lower part of a funnel beaker of light blue-green transparent glass with small bubbles. Vessel diameter 4 cm. Sherd size 25 mm × 15 mm. Wall thickness 2-3 mm. Dating: mid-8th century. Inv.-No. SH2013-704.12.

Nieblum LA 67

Pit house AU2016-17/9 – 9th century

KHa 117: Fragment (quarter) of a polychrome ring-shaped bead of dark green translucent glass with thin horizantal white opaque trails on the outside edges. Length 5 mm. Diameter 10 mm. Dating: 9th century. Inv.-No. SH2016-17.66.

KHa 118: Wall sherd of a funnel beaker of blue-green transparent glass with small bubbles. Diameter of lower funnel part 26 mm. Sherd size 9 mm × 12 mm. Wall thickness 1.3-1.8 mm. Dating: 9th century. Inv.-No. SH2016-17.113.

Witsum LA 146

Pit house AU2016-137/1 – Mid-8th century

KHa 119: Wall sherd of a polychrome globular beaker of blue-green transparent glass with small bubbles and five horizontal trails of vivid yellow opaque glass. Vessel diameter 7-8 cm. Sherd size 25 mm × 21 mm. Wall thickness 1.8 mm. Dating: mid-8th century. Inv.-No. SH2016-137.186.

KHa 156: Fragment (halve) of a barrel-shaped bead of dark blue translucent glass. Length 8 mm. Diameter 6 mm. Hole diameter 2 mm. Dating: mid-8th century. Inv.-No. SH2016-137.188.

Pit house AU2016-137/49 – Mid-8th century

KHa 120: Wall sherd of a polychrome vessel, possibly a globular beaker, of blue-green transparent glass with small bubbles and a horizontal reticella-trail of vivid yellow opaque and blue-green transparent glass. Sherd size 11 mm × 14 mm. Wall thickness 1.8-2.0 mm. Dating: mid-8th century. Inv.-No. SH2016-137.357.

KHa 121: Small wall sherd of light blue-green transparent glass with small bubbles. Sherd size 12 mm × 11 mm. Wall thickness 0.8-1.0 mm. Dating: mid-8th century. Inv.-No. SH2016-137.364.

KHa 122: Fragment (halve) of a monochrome barrel-shaped bead of dark red opaque glass. Length 5 mm. Diameter 6 mm. Hole diameter 1.5 mm. Dating: mid-8th century. Inv.-No. SH2007-607.385.

KHa 124: Tessera of irregular rectangular shape with sharp edges of light blue opaque glass. Size 11×8×10mm. Dating: mid-8th century. Inv.-No. SH2007-607.375.

KHa 157: Fragment of a lozenge-shaped gaming piece or inlay with a flat bottom and a domed upper side. Dark brown translucent glass with a marvered double reticella rod of colourless transparent glass with white opaque trails. Diameter 4mm×12mm. Thickness 6mm. Dating: mid-8th century. Inv.-No. SH2007-607.313.

KHa 158: Small wall sherd of light blue-green transparent glass with small bubbles. Sherd size 4.5mm×8mm. Wall thickness 1.8-2.0mm. Dating: mid-8th century. Inv.-No. SH2016-137.356.

KHa 159: Wall sherd of a polychrome globular beaker of blue-green transparent glass with small bubbles and seven horizontal trails of vivid yellow opaque glass. Vessel diameter 7-8cm. Sherd size 18mm×26mm. Wall thickness 1.8-2.0mm. Dating: mid-8th century. Inv.-No. SH2016-137.363.

KHa 160: Fragment (halve) of a polyhedral bead of dark blue translucent glass with four applied dots of dark red opaque glass. Length 11mm. Diameter 7mm. Hole diameter 4mm. Dating: mid-8th century. Inv.-No. SH2016-137.376.

KHa 161: Wall sherd of a polychrome vessel of light blue-green transparent glass with small bubbles and a reticella-trail of dark blue transparent and light blue-green transparent glass. Sherd size 18mm×16mm. Wall thickness 1.7mm. Dating: mid- to late 8th century. Inv.-No. SH2016-137.377.

Pit house AU2016-137/72 – Late 8th century

KHa 123: Wall sherd of a mould-blown funnel beaker with vertical ribbing of light blue-green transparent glass with small bubbles. Sherd size 16.5mm×13mm. Wall thickness 0.8-1.6mm. Dating: mid- to late 8th century. Inv.-No. SH2016-137.492.

KHa 162: Wall sherd of a mould-blown funnel beaker with vertical ribbing of light blue-green transparent glass with small bubbles. Sherd size 14mm×11mm. Wall thickness 0.6-1.0mm. Dating: mid- to late 8th century. Inv.-No. SH2016-137.500.

KHa 163: Wall sherd of a polychrome vessel of light blue-green transparent glass with small bubbles with three parallel marvered trails of vivid yellow opaque glass. Sherd size 3.5mm×7.5mm. Wall thickness 1.2-1.7mm. Dating: mid- to late 8th century. Inv.-No. SH2016-137.515.

KHa 164: Small wall sherd of a polychrome vessel, possibly a funnel beaker, of light blue-green transparent glass with small bubbles and a vertical reticella-trail of light blue-green transparent and white opaque glass. Vessel diameter approx. 8cm. Sherd size 12mm×11mm. Wall thickness 0.8-1.0mm. Dating: mid- to late 8th century. Inv.-No. SH2016-137.535.

KHa 165: Partially reconstructed claw of a claw beaker of dark blue transparent glass with small bubbles. Preserved claw size 42mm×23mm. Wall thickness of beaker 1.5-2mm. Wall thickness of claw 1.0-4.6mm. Dating: 7th century. Inv.-No. SH2016-137.536.

KHa 166: Small wall sherd of a polychrome vessel of light blue-green transparent glass with small bubbles with two parallel marvered trails of vivid yellow opaque glass. Sherd size 8.5mm×6mm. Wall thickness 0.5mm. Dating: mid- to late 8th century. Inv.-No. SH2016-137.568.

Nieblum Goting LA 151

Pit house AU2017-31/1 – Late 8th century

KHa 188: Rim sherd of a polychrome vessel, probably a wide palm cup or bowl, of dark green transparent glass with small bubbles. The rim is folded outward and decorated with thin, marvered opaque yellow trails. Sherd size 19mm×7mm. Wall thickness 1.5-2.5mm. Inv.-No. SH2017-31.115.

KHa 189: Rim sherd of a monochrome funnel beaker of olive-green transparent glass with small bubbles and molten, slightly thickened rim. Sherd size 12mm×13mm. Wall thickness 1.8-2mm. Inv.-No. SH2017-31.182.

KHa 190: Rim sherd of a monochrome funnel beaker of light blue-green transparent glass with small bubbles and molten, slightly thickened rim. Sherd size 10mm×14mm. Wall thickness 1-1.7mm. Inv.-No. SH2017-31.184.

CHEMICAL ANALYSIS ON NORTH FRISIAN GLASS OBJECTS

Methodology and Research questions

In total, 41 samples were taken from the original objects at the Archaeological Museum Schloss Gottorf in Schleswig (V. Hilberg and G. Stawinoga for the Tinnum samples) and at the Electron Microprobe Laboratory of Göttingen University (A. Kronz). Each sample was analysed for 20 elements via Electron Microprobe (EPMA)[40], and for 65 major and trace elements LaICPMS[41]. The results on the most important elements are provided in **tabel 1**.

The objects were analysed as part of the series of glass samples in connection with the Cologne Harbour project[42] in order to gain a broad geographic distribution of products, which were possibly produced at the Cologne Harbour glass workshops or at related glass workshops in the Rhineland. The North Frisian trading sites were especially promising as probable profiteers of the Frisian-based trade along the North Sea coast between the Rhine estuary and Scandinavia. The chemical analysis aims to answer the following research questions:

Which main types of glass (compositional groups) can be found? Do the glass types, whose chronological occurrence is fairly well known, fit or contradict the archaeological dating of the sampled finds?

Is it possible to identify »production groups« within the sampled glass objects? This regards mainly the identifiable subtypes within the main glass types, which can be differentiated by specific geochemical signatures of the raw materials or local variations in glass recipes. »Production groups« can provide a contribution to determine the origin of glass objects. However, certain chemical signatures can only reflect the original signature of the raw-glass production workshop, while other parameters might be altered with every further processing step in secondary glass workshops.[43] Glasses with a uniform signature of chemical components, which result from non-intentional constituents from their raw materials, may therefore only be regarded as a characteristic of one raw-glass production workshop or a limited region of production, possibly in a very limited timeframe. Evidence for the secondary workshops is more difficult to obtain, but every additional processing step induces changes in the glass chemistry. These changes may include losses of Alkalis and Chlorine, possible element migration from the crucible walls (K, Al, Ti?) and fly ash from the furnace (K, Mg).

Is it possible to detect similarities between samples? Can samples be found to be chemically identical and therefore be attributed to origin from the same vessel or the same melted charge (»batch«) of glass; attributed to a certain »workshop« through only small variations in their base glass (e.g. from added colourants), within an assumed limited timeframe; attributed to a subtype (»production group«) and therefore part of a type of raw glass with a chronological and geographical limitation?

Can re-use and recycling be proven in the samples? Which chemical similarities can be found between vessel glass, which was possibly imported as cullet for recycling, and the beads? Were the beads of local produce?

Can glass objects from the North Frisian Islands be connected within and across their specific chemical groups and sites; with glass finds from other sites along the North and Baltic Sea Coastal, such as Amrum, Cuxhaven-Altenwalde, Groß Strömkendorf / Reric, Rostock-Dierkow or Haithabu / Hedeby; with other sites from the analytical database and especially with the glass objects from the harbour of Cologne? Can a provenance be proven for some samples?

Main glass types

Based on the compositions or recipes of raw materials for glass production, especially the fluxing agent, three main glass types can be differentiated and may be considered in the analysis. These are soda-lime glass

Sample label Göttingen No	Locality-1	Locality-2	Type-1	Type-2	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O
KHa 149	Sylt	Tinnum	SLGM	modern	71.57	0.05	0.54	0.18	<0.024	0.30	14.59	11.91
KHa 150	Sylt	Tinnum	nn	cruc MIG Mn	64.43	0.14	5.73	0.89	5.45	0.32	10.92	8.62
KHa 152	Sylt	Tinnum	MAG	SAG Fsp-glas	61.29	0.11	10.33	1.58	0.07	0.75	5.90	9.86
KHa 122	Föhr	Witsum	SAG	SAG-Pb	56.92	0.18	2.21	1.96	0.51	2.02	7.72	13.41
KHa 141	Sylt	Tinnum	SLG	Lev-1	70.28	0.07	2.76	0.38	<0.024	0.57	7.59	15.75
KHa 151	Sylt	Tinnum	SLG	Lev-1	70.82	0.08	2.72	0.53	<0.024	0.63	7.16	15.69
KHa 146	Sylt	Tinnum	SLG	Lev-1	69.27	0.08	2.86	0.51	0.03	0.71	6.67	16.21
KHa 148	Sylt	Tinnum	SLG	Lev-1	68.68	0.08	2.93	0.52	<0.024	0.76	7.85	14.59
KHa 153	Sylt	Tinnum	SLG	Lev-1	68.83	0.08	3.12	0.51	<0.024	0.71	8.34	13.80
KHa 114	Sylt	Tinnum	SLG	HIMT-2	68.73	0.10	2.59	0.67	0.33	0.84	7.80	16.42
KHa 115	Sylt	Tinnum	SLG	HIMT-2	69.14	0.10	2.60	0.70	0.34	0.82	7.69	16.41
KHa 155	Sylt	Tinnum	SLG	HIMT-2	69.45	0.09	2.59	0.69	0.34	0.83	7.74	16.52
KHa 144	Sylt	Tinnum	SLG	HIMT-2	67.60	0.11	2.58	0.62	0.10	0.85	8.10	16.20
KHa 140	Sylt	Tinnum	SLG	HIMT-2	68.02	0.11	2.59	0.90	0.33	0.94	7.44	16.30
KHa 143	Sylt	Tinnum	SLG	HIMT-2	68.04	0.11	2.56	0.85	0.32	0.95	7.45	16.36
KHa 145	Sylt	Tinnum	SLG	HIMT-2	68.15	0.11	2.61	0.81	0.34	0.93	7.37	16.41
KHa 118	Föhr	Nieblum	SLG	HIMT-2	68.43	0.13	2.42	0.82	0.68	0.91	6.93	17.23
KHa 166	Föhr	Witsum	SLG	HIMT-2	68.96	0.09	2.47	0.82	0.60	0.71	7.00	17.23
KHa 121	Föhr	Witsum	SLG	HIMT-2	68.10	0.12	2.48	0.85	0.58	0.79	6.91	17.44
KHa 123	Föhr	Witsum	SLG	HIMT-2	67.96	0.11	2.48	0.97	0.54	0.76	6.85	17.21
KHa 162	Föhr	Witsum	SLG	HIMT-2	68.92	0.11	2.47	0.82	0.54	0.76	6.99	17.34
KHa 164	Föhr	Witsum	SLG	HIMT-2	68.54	0.11	2.50	0.92	0.43	0.73	6.87	16.91
KHa 190	Föhr	Goting	SLG	HIMT-2	67.28	0.14	2.71	1.19	0.68	0.96	7.14	16.54
KHa 189	Föhr	Goting	SLG	HIMT-2	66.25	0.17	2.62	1.28	0.83	0.94	6.53	17.21
KHa 117	Föhr	Nieblum	SLG	HIMT-2	65.11	0.11	2.45	1.09	0.47	0.65	6.63	15.63
KHa 165	Föhr	Witsum	SLG	HIMT-2	68.60	0.05	2.29	0.86	0.41	0.64	7.07	16.63
KHa 156	Föhr	Witsum	SLG	HIMT-2	68.82	0.09	2.32	1.00	0.49	0.66	6.81	17.20
KHa 163	Föhr	Witsum	SLG	HIMT-2	67.58	0.11	2.46	0.96	0.51	0.80	6.65	17.23
KHa 120	Föhr	Witsum	SLG	HIMT-2	67.24	0.09	2.40	0.92	0.49	0.83	6.53	17.39
KHa 119	Föhr	Witsum	SLG	HIMT-2	66.89	0.11	2.34	0.90	0.51	0.81	6.25	17.73
KHa 159	Föhr	Witsum	SLG	HIMT-2	67.16	0.10	2.34	0.91	0.51	0.80	6.32	17.71
KHa 188	Föhr	Goting	SLG	HIMT-2	66.35	0.10	2.22	0.84	0.64	0.87	6.36	17.57
KHa 157	Föhr	Witsum	SLG	HIMT-2	68.57	0.13	2.55	0.97	0.40	0.73	6.10	18.17
KHa 116	Sylt	Wenningstedt	SLG	HIMT-2	67.67	0.09	2.24	0.78	0.53	0.82	6.49	18.11
KHa 147	Sylt	Tinnum	SLG	HIMT-2	66.86	0.11	2.41	0.87	0.78	0.89	6.21	18.51
KHa 142	Sylt	Tinnum	SLG	HIMT-2 PbSn	48.64	0.08	2.01	0.72	0.35	0.56	4.77	13.39
KHa 166ge	Föhr	Witsum	SLG	HIMT-2 PbSn	44.92	0.09	2.25	0.56	0.12	0.43	4.07	10.59
KHa 163ge	Föhr	Witsum	SLG	HIMT-2 PbSn	47.63	0.10	1.92	0.62	0.29	0.50	4.61	12.25
KHa 158	Föhr	Witsum	SLG	HIMT-2	67.16	0.18	2.26	0.96	1.02	0.91	6.00	19.23
KHa 161	Föhr	Witsum	SLG	HIMT-2	67.49	0.15	2.27	1.00	0.80	0.89	6.19	18.96
KHa 160	Föhr	Witsum	SLG	HIMT-2	67.12	0.20	2.45	1.34	0.74	0.88	6.57	18.94
KHa 154	Sylt	Tinnum	SLG	Rom-bg?	70.23	0.19	1.44	0.62	0.04	0.80	6.93	18.29

Tab. 1 Chemical copmposition of sampled glass finds from Sylt and Föhr. Listed are the main, secondary and selected trace elements (oxide data: electron microprobe in mass-%, elements: La-ICPMS (ICP) in µg/g). – (Table B. S. Majchczack, A. Kronz).

K_2O	P_2O_5	SO_3	Cl	CuO	PbO	SnO_2	As_2O_5	Sb_2O_5	wt-total	Co-ICP	Sr -ICP	Zr-ICP	Sn-ICP	Sb-ICP	Pb-ICP
0.11	0.02	0.67	0.07	<0.040	<0.051	<0.027	0.08	<0.030	100.11	0.9	83	20	1	1	22
2.30	0.07	0.28	0.03	<0.041	<0.049	<0.028	<0.047	<0.030	99.34	9.4	259	156	4	6	70
5.10	0.27	0.05	0.34	3.23	0.06	1.39	<0.046	<0.032	100.38	4.3	74	211	10286	78	438
1.75	0.75	0.19	0.82	2.72	8.23	0.45	<0.050	0.23	100.24	39.8	624	74	3205	1838	79555
0.44	0.04	0.15	0.91	1.10	0.05	0.05	<0.046	<0.029	100.26	1.9	397	45	366	9	548
0.53	0.03	0.12	0.94	1.18	0.06	0.08	<0.047	<0.028	100.68	2.4	394	49	513	12	528
0.59	0.06	0.09	0.92	2.30	0.18	0.06	<0.046	<0.028	100.60	3.7	387	54	462	14	1758
0.35	0.04	0.08	0.95	2.12	1.51	0.08	<0.045	<0.029	100.63	2.0	362	52	940	134	14460
0.39	0.04	0.06	0.89	2.00	0.96	0.03	<0.046	<0.029	99.84	3.2	437	45	437	8	10624
0.88	0.14	0.17	0.84	<0.039	<0.049	<0.026	<0.046	0.09	99.80	14.1	485	59	68	689	369
0.88	0.14	0.18	0.82	<0.040	0.07	<0.027	<0.046	0.08	100.11	12.1	483	58	71	661	360
0.91	0.15	0.17	0.83	<0.039	<0.051	0.03	<0.047	0.08	100.58	13.5	477	58	70	718	377
0.69	0.10	0.14	0.76	1.54	0.52	0.09	<0.045	0.04	100.21						
0.89	0.15	0.18	0.82	1.15	0.11	0.05	<0.045	0.05	100.12	8.9	491	63	348	482	998
0.90	0.14	0.18	0.82	1.24	0.10	0.05	<0.046	0.05	100.18	9.2	488	62	418	485	1128
0.91	0.15	0.19	0.82	1.26	0.12	0.06	<0.046	0.06	100.39	9.2	482	62	427	488	1165
0.96	0.16	0.21	0.91	0.07	0.15	0.05	<0.046	0.22	100.33	18.4	465	76	268	1580	1626
0.82	0.14	0.18	0.87	0.11	0.45	0.07	<0.044	0.22	100.80	18.2	461	63	617	1884	3978
0.87	0.14	0.23	0.89	0.23	0.67	0.12	<0.045	0.29	100.80	21.4	464	72	905	2122	6671
0.79	0.14	0.21	0.87	0.23	0.54	0.07	<0.046	0.30	100.12	18.2	465	78	686	2262	6033
0.77	0.14	0.20	0.85	0.19	0.61	0.11	<0.045	0.26	101.14	20.7	458	67	689	2327	5822
0.81	0.14	0.20	0.82	0.20	0.95	0.14	<0.046	0.33	100.69	18.8	448	64	1028	2322	9500
1.25	0.25	0.17	0.75	0.21	0.71	0.09	<0.046	0.25	100.46	26.6	475	79	711	1860	7628
1.21	0.17	0.22	0.84	0.50	1.05	0.16	<0.045	0.25	100.40	27.9	482	95	1637	1961	15205
1.14	0.16	0.17	0.83	1.80	3.41	0.49	<0.047	0.26	100.48	51.6	418	61	4315	2096	34135
0.55	0.09	0.30	0.85	0.27	0.30	<0.027	<0.046	1.86	100.95	458.0	444	47	122	13965	2946
0.58	0.12	0.33	0.95	0.28	0.37	0.03	<0.046	1.60	101.80	548.1	448	56	126	11152	3854
0.83	0.13	0.24	0.84	0.35	1.25	0.16	<0.046	0.41	100.61	36.0	451	71	1248	2959	11130
0.75	0.15	0.26	0.88	0.59	1.59	0.18	<0.045	0.55	100.93	30.6	454	65	1252	4637	13655
0.76	0.12	0.30	0.94	0.67	1.54	0.18	<0.047	0.86	101.00	33.8	441	68	1397	5186	17170
0.74	0.12	0.28	0.94	0.60	1.39	0.16	<0.046	0.77	100.96	77.0	437	64	1047	6079	11669
0.77	0.15	0.30	0.93	0.64	1.45	0.09	<0.046	1.23	100.60	33.0	463	55	663	8473	13820
0.63	0.10	0.28	0.96	0.59	0.24	0.05	<0.046	1.01	101.60	237.6	431	66	470	8876	2284
0.63	0.12	0.28	0.93	0.41	1.00	0.11	<0.046	0.81	101.09	24.6	461	61	865	5828	9164
0.63	0.12	0.28	1.02	1.69	0.60	0.05	<0.046	0.28	101.40	13.1	443	62	512	2014	5775
0.47	0.08	0.22	0.67	0.32	25.53	1.86	0.55	0.70	100.93	46.4	305	46	25865	6013	264100
0.50	0.05	0.11	0.43	0.09	33.75	2.00	<0.055	0.09	100.07						
0.63	0.12	0.15	0.47	0.21	28.28	2.51	0.09	0.28	100.69						
0.54	0.08	0.30	1.12	0.22	0.40	0.05	<0.045	0.40	100.92	41.2	453	98	302	3037	4302
0.58	0.07	0.31	1.11	0.27	0.49	0.06	<0.045	0.60	101.30	116.4	454	90	354	3835	4559
0.53	0.07	0.27	1.07	0.22	0.39	0.04	<0.046	0.59	101.53	335.6	489	106	380	4433	4849
0.47	0.06	0.24	1.08	<0.039	0.07	<0.026	<0.045	<0.028	100.58	2.2	561	105	6	3	466

Tab. 1 (continued).

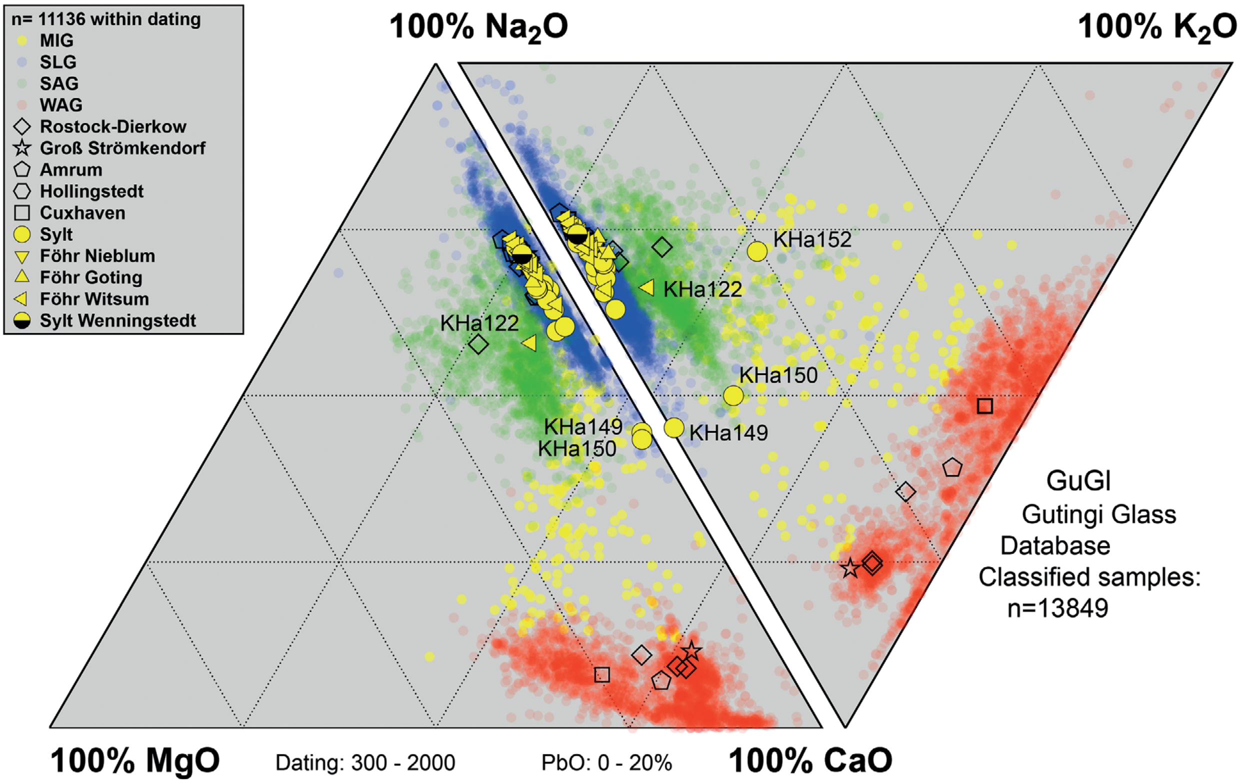


Fig. 6 Glass composition, charted in the doubled ternary-systems of Na_2O-CaO-MgO and Na_2O-K_2O-CaO. **Red**: Wood-ash glass types (WAG, WALG). – **Green**: Soda-ash glass (SAG). – **Blue**: Soda-lime glass (SLG) and Mixed-alkali- und mixed glasses (MAG, MIG). – **Small points**: Data from published research and unpublished, own analysis data. – (After Kronz 2020, fig. 1).

(SLG), soda-ash glass (SAG) and wood-ash glass (WAG)[44]. While the two latter types use different plant ashes as a fluxing agent, the soda-lime glass is based on lime and mineral soda. Its main component is trona ($Na_3H(CO_3)_2 \cdot 2\,H_2O$), which was mined nearly exclusively, according to current state of research, from deposits in Egypt. Soda-lime glass is the dominant glass type in Antiquity and the Early Medieval Period in Europe. **Figure 6** shows the composition of the glass samples from Föhr and Sylt within a doubled ternary-system of Na_2O-CaO-MgO and Na_2O-K_2O-CaO. The chart is especially suited to differentiate the main glass types. It includes > 13 000 glass sample data points from various published research, collected in a joint database, coloured according to the main glass types and filtered for dates from AD 300.

Apart from a few exceptions still to be discussed, almost all examined glass finds from Föhr and Sylt can be identified as SLG. The glass composition corresponds to thousands of antique and early medieval glass compositions (blue points in **fig. 6**). According to the present state of knowledge, the wood-ash glass that appeared in the last quarter of the 8th century[45] cannot be proven in any sample, which can certainly be interpreted as *terminus ante quem* and confirms the archaeological dating.

Several samples with anomalous compositions are discussed in detail: The only flat glass (KHa 149, a soda-lime glass) found at Sylt (Tinnum) can be identified with certainty as modern glass. The concentrations of certain chemical elements are such low (Fe, Sn, Sb, rare earths, Sr) that the starting components used for production must come from chemically processed raw materials. This composition is only achievable with chemical soda, so that this glass dates from the 19th century at the earliest, but rather to the 20th century. Moderate arsenic contents (> 700 µg/g As) for decolourization also speak for a modern glass. It will not be considered further in the following.

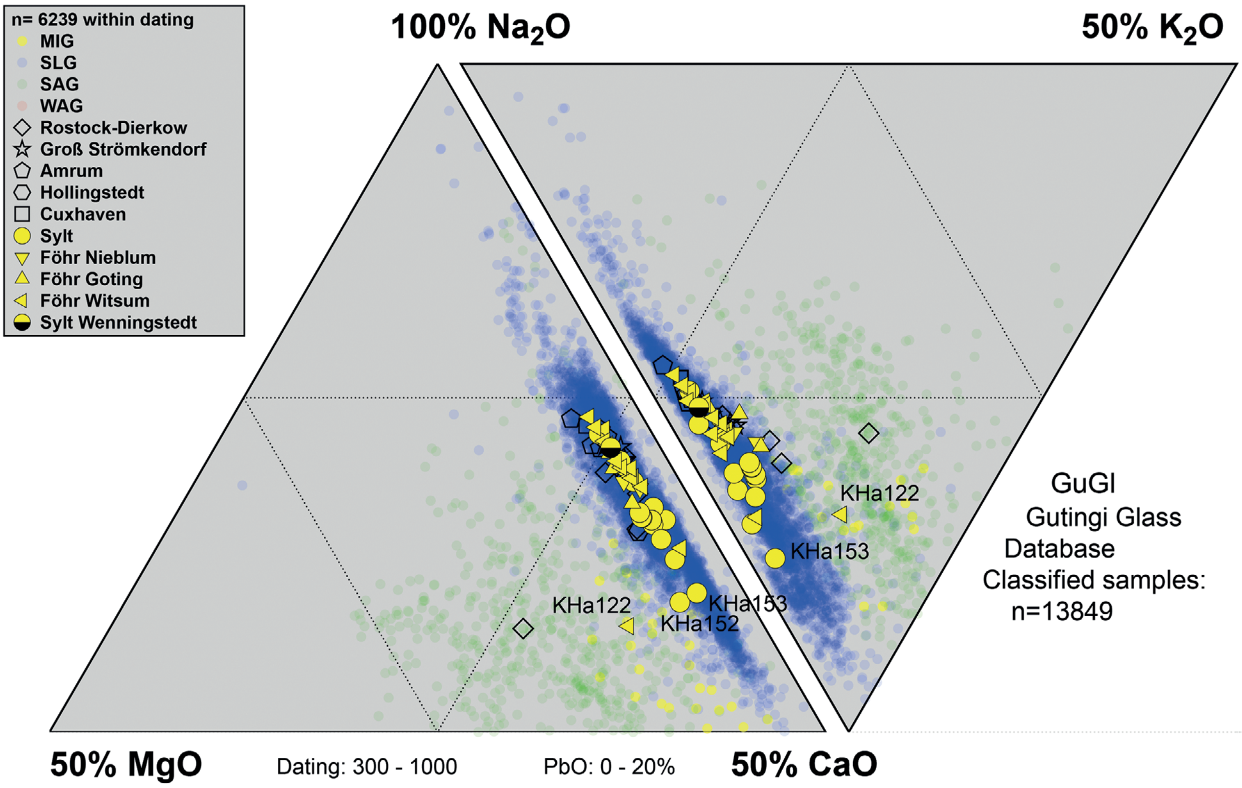


Fig. 7 Glass composition as in **fig. 6**, reduced to 50 % CaO, K_2O und MgO each. With exceptions, the glass finds from Sylt tend to have lower Na_2O/CaO ratios than those from Föhr. Only glass samples in the dating period AD 400-1000 are included. – (After Kronz 2020, fig. 2).

The sample KHa 150 cannot be clearly classified into a historical glass group. The glass lump is strongly corroded, the interior consists of an intact brown glass with a very high manganese content (5.45 % MnO). In the Na-Mg-Ca ratios it corresponds to the modern window glass KHa 149, but differs significantly in the trace element content. The manganese addition is intentional to achieve a brown colouration. If it was an early medieval glass, a tessera fragment would be conceivable as an added colourant. However, the chemical composition does not find any analogues in published analyses. An interpretation as submodern glass is probable, at least in this respect.

An exception to the main glass type SLG is the sample KHa 152, which can be described as mixed alkaline glass (MAG). The opaque orange-dark red glass bead from Sylt (Tinnum) is a speciality in this respect, because it belongs to a quite rare glass type due to its very unusual chemical composition. Its high aluminum content and a very low Zr/Hf ratio allow a clear classification. The origin is to be found in the Indo-Pacific region, probably Northern India. Analogous beads are presented for Ribe/Denmark[46]. Due to the high Al content, some calcium and alkalis were introduced via feldspar, so it is not clear whether plant ash or a mineral soda raw material was used as a further source of alkalis.

The red glass bead KHa 122 is also an exception and can be identified as soda-ash glass (SAG), which was produced from sodium-rich plant ash from beach plants and a raw material containing SiO_2. Analogous beads from the Scandinavian region are classified as »Group 1&2«[47] and partly interpreted as potentially recycled waste glass. For the bead KHa 122 a mixed glass of SLG and wood-ash glass would be possible, but very unlikely regarding the dating, therefore it is either a SLG which is quite strongly contaminated with wood ash or (more likely) a SAG.

All other objects belong to the soda-lime glass type. Their chemical variation reflects a rather uniform glass formulation with respect to the higher concentrated major elements, but allows groupings in the Na_2O-CaO ratios, which also tend to separate the finds from Sylt and Föhr (**fig. 7**). This grouping suggests different production groups, which will be examined in more detail below.

Glass subtypes or production groups

From the beginning of the first millennium AD onwards, soda-lime glass (SLG) was the dominant glass type in Western Europe. Surprisingly, its chemical composition in Roman times varied only within very narrow limits. On the one hand, this was attributed to a strict adherence to recipes despite an allegedly large spread of primary glassworks throughout the entire Roman Empire[48], while an alternative interpretation sees in it a limitation of Roman primary glass production to very few locations, as demonstrated in the Levant with very large tank furnaces[49].

With the unambiguous proof[50] that the Roman glassworks in the Hambach Forest are not primary glassworks[51], a Roman primary glass production north of the Alps is also generally more and more questioned. If it existed at all, it had at most a marginal importance outside the mentioned large production centres. Interestingly, this situation does not seem to change in the Early Medieval Period. Primary glass production cannot be expected for the early Middle Ages either; rather, the proportion of recycled waste glass increases during periods of scarce resources[52]. Nevertheless, the material flow of raw glass from the Levant and Egypt seems never to have been completely interrupted until the $9^{th}/10^{th}$ century.

If we divide the late antique to early medieval soda-lime glass (SLG) into subtypes, the following results can be recorded for the glass samples from Sylt and Föhr (**fig. 8-9**):

Almost all glass objects are restricted to two production groups, which can be classified as »Levantine-1« and »HIMT-2« (»High-Iron-Manganese-Titanium«)[53]; actual classical roman glass (type »Roman-«) is missing with two (uncertain) exceptions. However, these exceptions are to be seen with the caveat that the transitions of Roman glass types to the so-called HIMT-2 type are fluent and a clear delimitation is difficult; late SLG types of the $8^{th}/9^{th}$ century (Egypt-1 and Egypt-2) are not encountered.

It should be noted that the HIMT-2 subtype is still defined very inconsistently: H. E. Foster and C. M. Jackson (2009) define in addition to HIMT-1 a late Roman glass group as »HIMT-2«. Compared to HIMT-1, HIMT-2 shows rather lower contents of the eponymous elements (Fe, Mn, Ti), but compared to Roman glass *sensu stricto* it is clearly enriched in these elements. In addition, the names »série 3.2«[54], »weak HIMT«[55] and a subtype »High Lime Iron Manganese Titanium«[56] are found in literature.

Figure 8 shows a variation diagram of the element oxide ratios Fe_2O_3/Al_2O_3 to Fe_2O_3/TiO_2. It is well suited to differentiate some production groups. However, other chemical systems must also be used for a more precise mapping. In this system, for example, the Egypt groups are strongly overlaid with HIMT-1. Especially these elements are specific to raw material and, at least in smaller quantities, were not added intentionally. They rather reflect the natural composition of the sand used in the raw glass production. The HIMT-2 subtype shows further distinct chemical variants, depending on chronology (**fig. 9**), which at least allow to clearly distinguish further subtypes, ranging until the end of the 4^{th} century and further from the 7^{th} century on, whereas in the period of the 5^{th}-6^{th} century both variants occur. Likewise, the late »HIMT-2« SLG of the 9^{th} century seems to differentiate itself again. These distinguishing criteria need to be refined in the future, as they certainly help to support the dating of glass.

Taking into account the analytical errors and scattering of the individual measurements in a sample, the Levantine-1 and HIMT-2 glasses and especially the samples from Sylt form self-contained groups, partly with chemically identical samples, which will be discussed below.

Apart from the already discussed exceptions to the main glass types are the samples KHa 154 and KHa 124 noteworthy. Sample KHa 154, a partly melted dark green rod end, is difficult to assign: Lower Al, Fe, Mn and Sb indicate a Roman type, higher Ti and Zr rather indicate HIMT. In the variation diagram **figure 8** the sample falls into the Egypt-1/-2 field, in **figure 9** it is assigned to HIMT-2. Both do not fit for all elements: It is possible that this sample represents an independent early medieval subtype, which is not yet found in the literature. There is an extremely good concordance with glasses of the 7th and 8th century from the Crypta Balbi in Rome [57].
Sample KHa 124 is a light blue tessera, coloured with little cobalt. Its Mn and very high Sb contents (as opacifier) fall within the range of Roman glass compositions. Therefore, it seems to be the only piece inherited from antiquity.

Similarities in composition between glass objects

In **tabel 1** as well as in **figure 10**, the samples are sorted according to their chemical similarity. However, the results are not always clear. Disturbing factors are the analytical error and the heterogeneity of the samples. Each sampled glass fragment was analysed with five individual separated points with the microprobe or two points with laser ablation (trace elements). Both variation variables are taken into account when specifying the scatter of a respective element.
Within this variation, some samples can be considered chemically identical and therefore could originate from a single object or directly from a melt batch:
Subtype Levantine-1: samples KHa 141, KHa 151.
Subtype HIMT-2: samples KHa 114, KHa 115, KHa 155; KHa 140, KHa 143, KHa 145; KHa 121, KHa 123, KHa 162; KHa 119, KHa 159 and KHa 158, KHa 161 (nearly identical).
In addition, numerous samples show quite strong similarities and therefore be classified as »same glass workshop« or at least, as far as the base glass is concerned, as »batch« [58] (**tab. 1**; **fig. 10**).

Origin of the beads

The vivid turquoise-blue beads of the Levantine-1 subgroup from Tinnum (KHa 148, KHa 153) were probably made directly from vessel glass (KHa 141, KHa 151 and KHa 146) (**fig. 10**). The base glass used for vessel glass production has a very uniform workshop signature. The samples KHa 141 and KHa 151 are probably from the same vessel. Although the iron contents of these samples differ slightly, this is due to heterogeneity within the samples. As a whole, all other element contents are very similar.
Differences can be found partly in the colouring elements (Cu) and especially in lead. This may be due to contamination from the crucibles or intentional variations in the bead making process. In principle, stronger chemical influences must be assumed in the bead production process, because in contrast to vessel or flat glass production, significantly smaller melting volumes are handled, which inevitably lead to a chemically heterogeneous product spectrum. Ash input and contamination from crucibles change the chemical signature of the glass much more than is the case in vessel or flat glass production. This can be deduced from increased K, Mg and Al contents.
The beads KHa 142 (Pb-Sn yellow opacified) and KHa 147 (dark blue-green) are similar despite the different colouration in the base glass. They are identified here as »HIMT-2«, but tend to the late Roman Sb and Mn decolourized glass (especially the Ca/Na ratio and the significantly higher Mn and Sb contents). Despite the different localities they are quite close to the vessel glass KHa 116 (Wenningstedt).

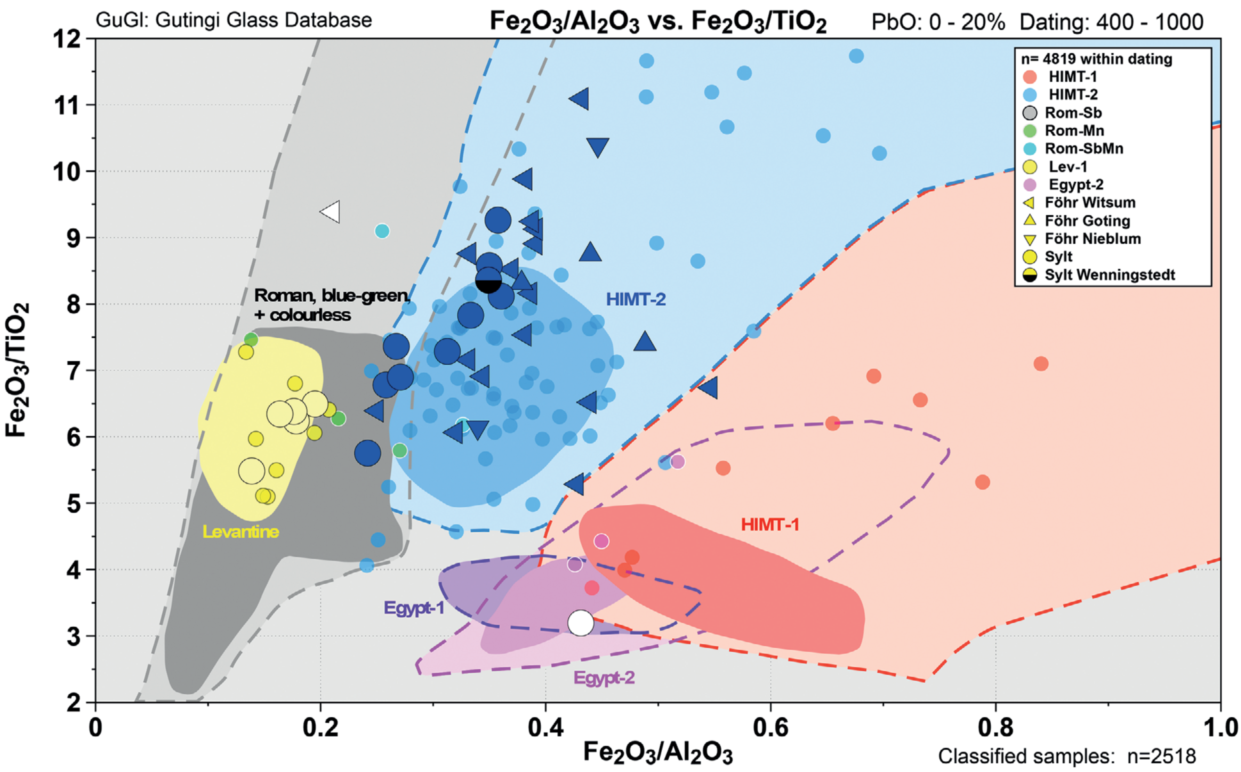


Fig. 8 Variation of glass composition in the system Fe_2O_3/Al_2O_3 – Fe_2O_3/TiO_2. **Yellow**: production group Levantine-1. – **Blue**: HIMT-2. – **Red**: HIMT-1. – **Large symbols**: Sylt und Föhr. – **Medium symbols**: Cologne. – **Small symbols**: other data from literature. Average error or scattering within individual samples is approx. 2 units in Fe_2O_3/TiO_2 and 0,07 in Fe_2O_3/Al_2O_3. Only glass samples in the dating period AD 400-900 are included. – (After Kronz 2020, fig. 3).

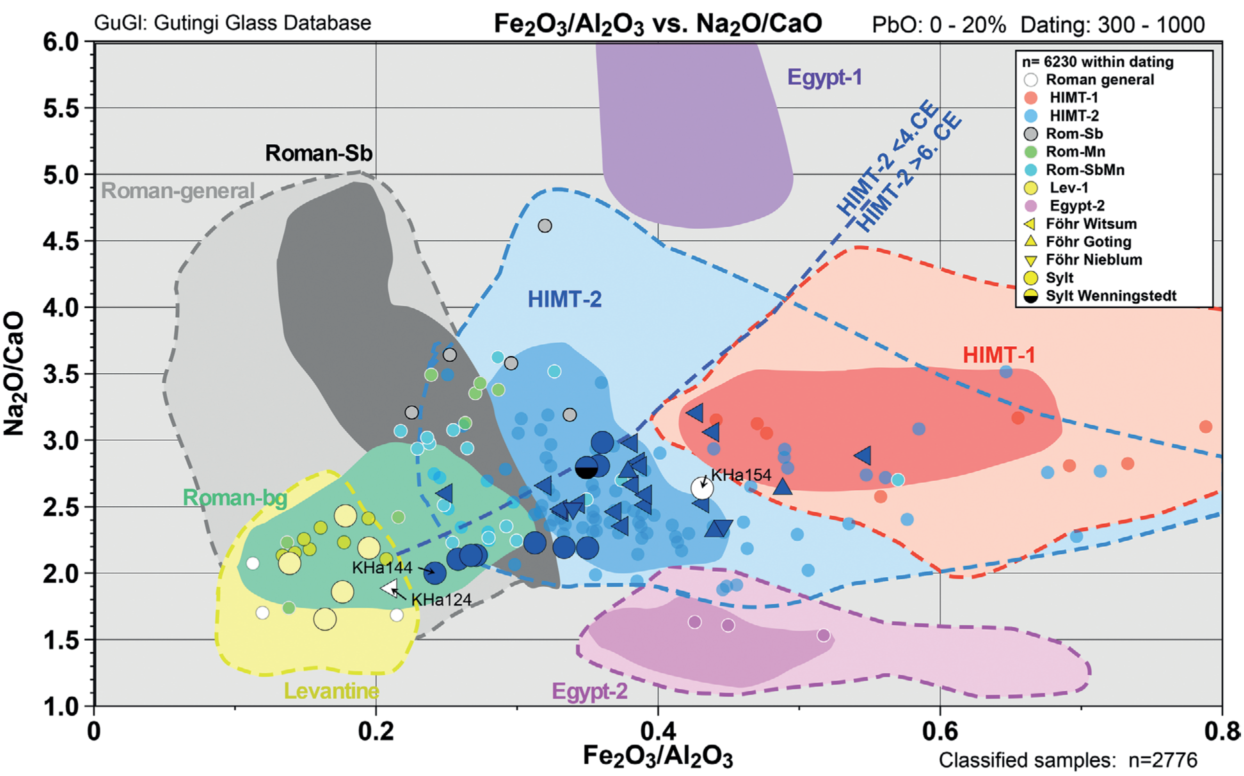


Fig. 9 Variation of glass composition in the system Fe_2O_3/Al_2O_3 – Na_2O/CaO. **Yellow**: production group Levantine-1. – **Blue**: HIMT-2. – **Red**: HIMT-1. – **Large symbols**: Sylt and Föhr. – **Medium symbols**: Cologne. – **Small symbols**: other data from literature. Average error or scattering within individual samples is approx. 0,1-0,2 in Na_2O/CaO and 0,07 in Fe_2O_3/Al_2O_3. Only glass samples in the dating period AD 400-900 are included. – (After Kronz 2020, fig. 4).

The bead fragment KHa 160 could have been made of glass with the chemical signature of the samples KHa 158 and KHa 161.
The possible gaming piece KHa 157, despite different colouring in the base glass, again resembles the vessel glass samples KHa 119 and KHa 159.
In general, the chemical composition and colouration of the samples shows the evident connection between beads and the vessel glass, proving a local bead-manufacture from vessel glass. Concerning the partly more intensive colouration of the beads, the bead makers seem to have understood to colour the glass batch more intensively with copper compounds, at least in case of the green colouration.

Recycling – reuse of glass cullet

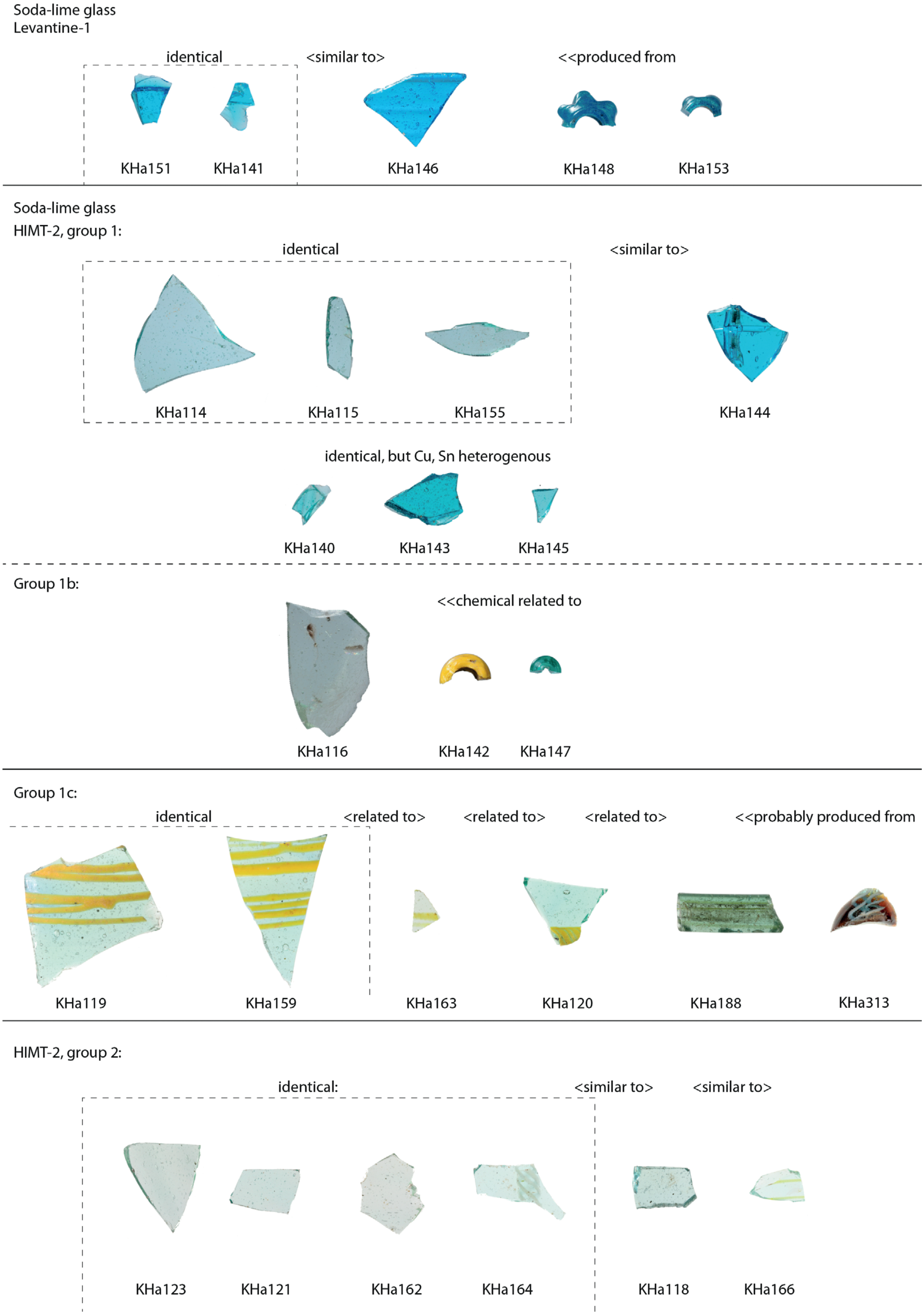
All samples from Sylt and Föhr are characterized by trace element contents of Co, Cu, Sb, Sn and Pb, whose concentration for all or some of the elements is significantly higher than the expected (geogenic) contents from the raw materials. This is partly due to intentional colouration with copper (Cu) in combination with lead (Pb) or cobalt (Co) as well as the addition of tin (Sn) or antimony (Sb) as opacifiers. For some samples, however, these element concentrations are lower than they would make sense for an intentional addition. The only explanation for this is the reuse of cullet, which, although it was probably recycled in a colour-sorted manner, always led to contamination, for example through the unavoidable addition of colourful decorative elements. The fact that glass recycling has been common practice since antiquity is described very comprehensively in the literature [59]. We have to assume that despite raw glass imports, the workshops that produced vessel glass always melted down cullet. For the production of beads, it can generally be assumed that cullet and tessera were used.

Comparison with samples from trading sites in the North Sea and Baltic region

If we include the glass from other sites in the North-Baltic Sea region, some similarities and differences can be observed (**fig. 11**):
In Groß Strömkendorf, Rostock-Dierkow, Cuxhaven-Altenwalde and Norddorf / Amrum some isolated wood-ash glasses are present, in Rostock-Dierkow also a soda-ash glass. Occasionally HIMT-1 is represented (Cuxhaven-Altenwalde, Norddorf / Amrum). Levantine-1 does not occur. The HIMT-2 subtype dominates the glass composition also in these places. The larger spectrum of different glass types shows a greater chronological variation for these sites, perhaps also more diverse trade contacts. Nevertheless, many samples are similar to the glass finds from Sylt and Föhr (**fig. 12-13**), so that a rather narrow timeframe and participation in the same, geographically limited import stream can be assumed for early medieval sites on the North Frisian Islands.

Comparison with samples from Haithabu / Hedeby

If we compare the chemical composition of the glass finds from Haithabu / Hedeby [60] with those from Föhr and Sylt, several differences emerge, which reflect a) a different time frame and b) a clearly different duration.


Soda-lime glass
Levantine-1
identical
<similar to>
<<produced from
KHa151
KHa141
KHa146
KHa148
KHa153
Soda-lime glass
HIMT-2, group 1:
identical
<similar to>
KHa114
KHa115
KHa155
KHa144
identical, but Cu, Sn heterogenous
KHa140
KHa143
KHa145
Group 1b:
<<chemical related to
KHa116
KHa142
KHa147
Group 1c:
identical
<related to>
<related to>
<related to>
<<probably produced from
KHa119
KHa159
KHa163
KHa120
KHa188
KHa313
HIMT-2, group 2:
identical:
<similar to>
<similar to>
KHa123
KHa121
KHa162
KHa164
KHa118
KHa166

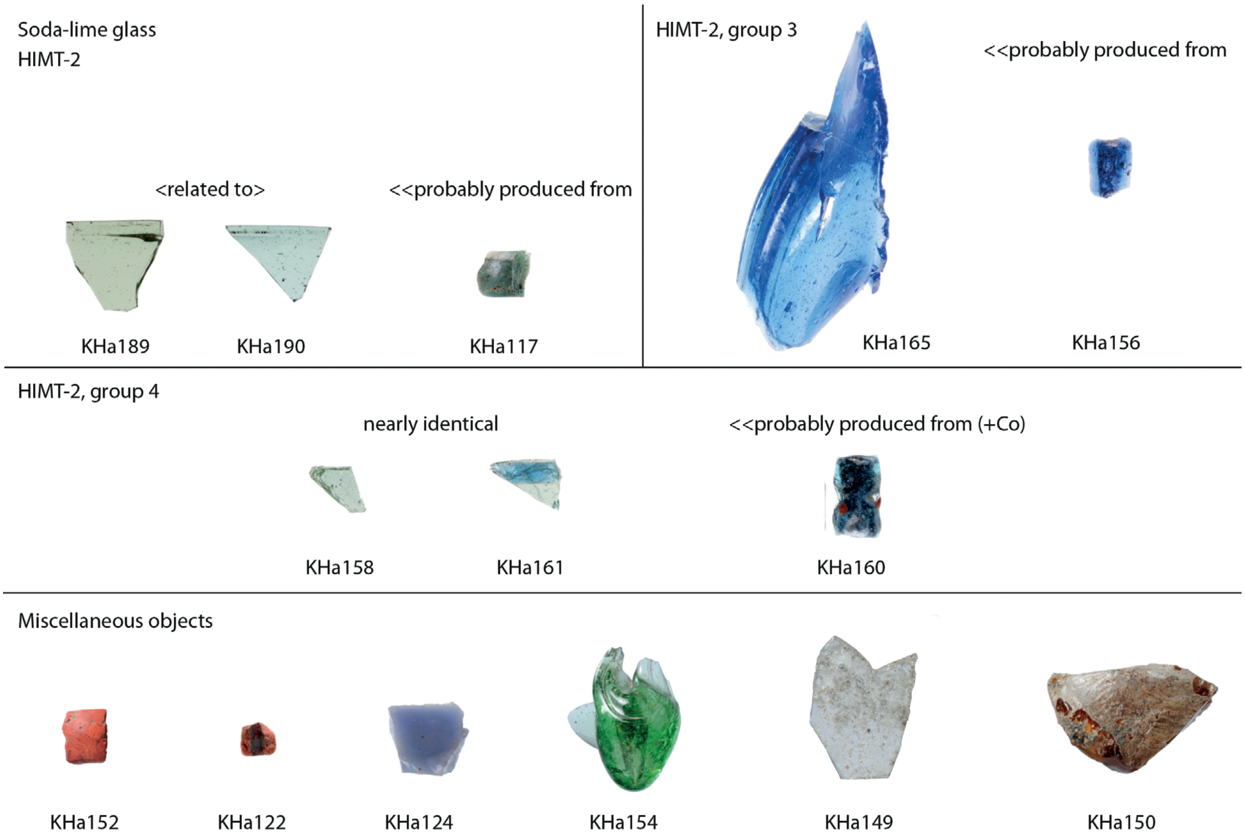


Fig. 10 (continued).

a) The glass finds from Hedeby include all known main glass types: Soda-ash glass (SAG), soda-lime glass (SLG) and wood-ash glass (WAG). As already mentioned above, sporadic early occurrences of WAG can be proven in the last quarter of the 8th century and only from the 9th century onwards, it becomes more widespread, although still with geographic limitations. In the Rhineland, WAG seems to play only a marginal role in the 9th century, but is not completely absent in this period[61].

In the case of Hedeby, SAG will have reached the trading centre via trade routes from the Middle East. However, the high proportion of SLG of the subtype »Egypt-2« in Hedeby is striking. It is present in very pure, non-contaminated samples, and therefore has not been recycled before. This subtype does not occur before the first half of the 9th century[62]. The absence of WAG, SAG and SLG of the production group »Egypt-2« in the pool of North Frisian samples supports a dating which assigns an age »before 775« to those glass finds.

b) The HIMT-2 glass subtype found on Föhr and Sylt is also represented in Hedeby, but is rather subordinate. This is due to the generally younger age of the samples from Hedeby, but nevertheless also shows the trade

Fig. 10 Images of the sampled glass finds according to chemical grouping. For all samples that were identified as chemically identical, the colour match also fits. For chemically similar samples, which indicate the same production type or workshop similarity, the groupings are also easy to trace in terms of morphology and colour. An exception is sample KHa 144, which is similar in colour to the Levantine-1 glasses, but chemically on the border of the HIMT-2 group and therefore closer to the group KHa 114, KHa 115, KHa 155. Many beads can be chemically correlated with hollow glass, which does not mean that they must have been made exactly from the adjacent pieces. – (Figure B. Majchczack after Kronz 2020, fig. 5; Pictures ©ALSH and R. Kiepe, NlhK).

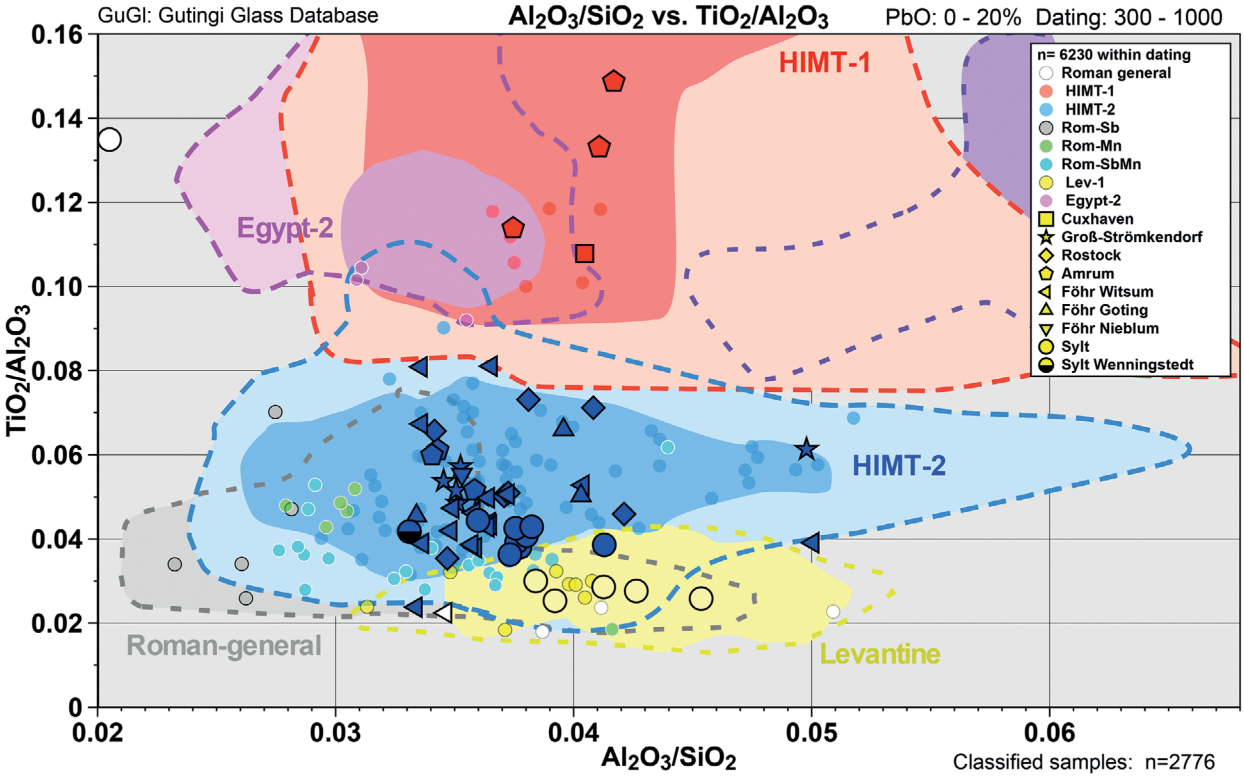


Fig. 11 Variation of glass compositions in the system Al_2O_3/SiO_2 – TiO_2/Al_2O_3. **Yellow**: production group Levantine-1. – **Blue**: HIMT-2. – **Red**: HIMT-1. – **Open symbols**: other main glass types. – **Large symbols**: samples from North Sea and Baltic area. – **Medium symbols**: Cologne. – **Small symbols**: other data from literature. Only glass samples in the dating period AD 400-900 are included. For Cologne and literature data only SLG is shown for better clarity. – (After Kronz 2020, fig. 6).

contacts with the Frankish Empire. A major reason, however, is the much longer persistence of the Hedeby trading site.

On Föhr and Sylt, the variation of the glass composition even within the found HIMT-2 group is limited to such a few chemically similar groups that it can be assumed that the glass was delivered from perhaps only a few places of origin.

Funnel beakers of the HIMT-2 subtype from Hedeby fit chemically well to the material from Sylt and Föhr.

Comparison with samples from Cologne harbour

HIMT-2 is the dominant glass type for the samples investigated from the area of the early medieval Cologne harbour. A clear similarity to the glass finds from Sylt and Föhr is recognizable, but ultimately this cannot be a proof of the origin of the glass vessels from Cologne workshops. **Figures 8** and **9** show the obvious similarities in the chemical composition, which can also be proven for the entire remaining elemental signature within the variations. From this point of view, a provenance of the vessel glassware from the Rhineland is to a certain degree probable and there is at least no objection against a provenance from the Cologne workshops.

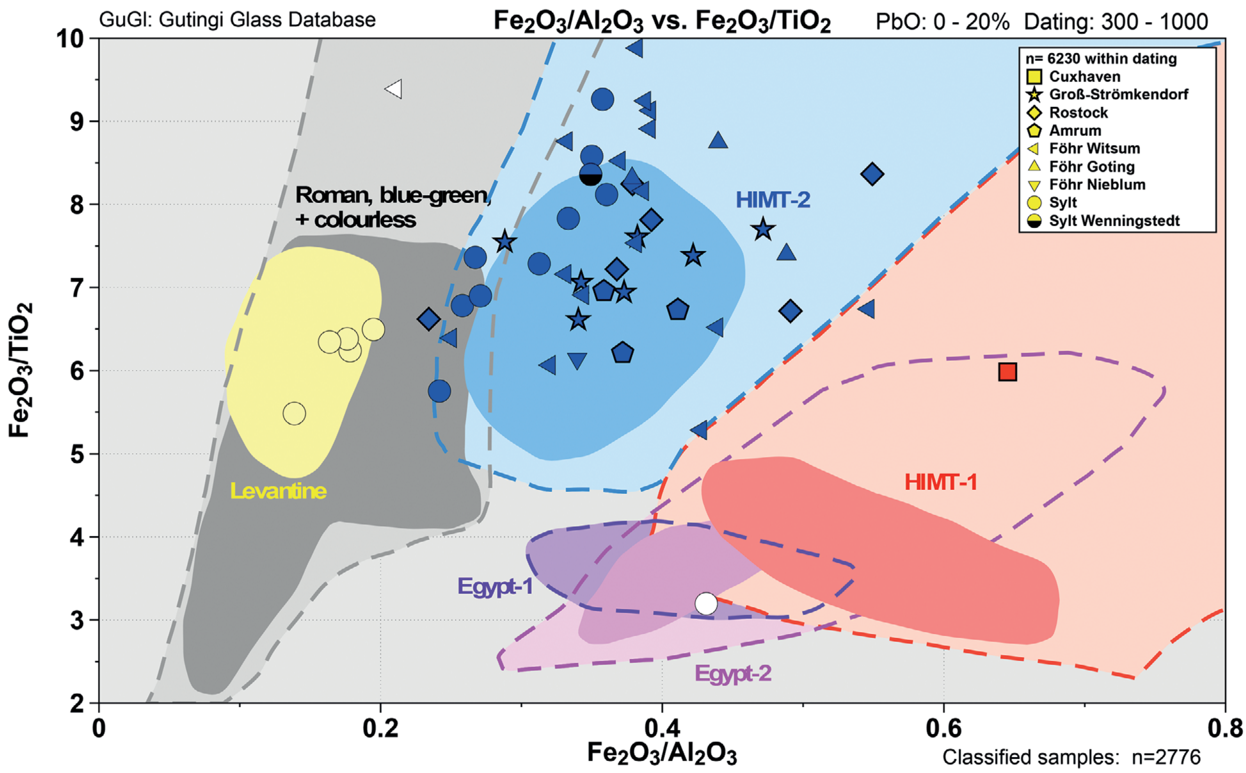


Fig. 12 Variation of glass compositions in the system Fe_2O_3/Al_2O_3 – Fe_2O_3/TiO_2. **Yellow**: production group Levantine-1. – **Blue**: HIMT-2. – **Red**: HIMT-1. – **Large symbols**: samples from North Sea and Baltic area. – **Medium symbols**: Cologne. – **Small symbols**: other data from literature. Only soda-lime glass samples in the dating period AD 400-900 are included. – (After Kronz 2020, fig. 7).

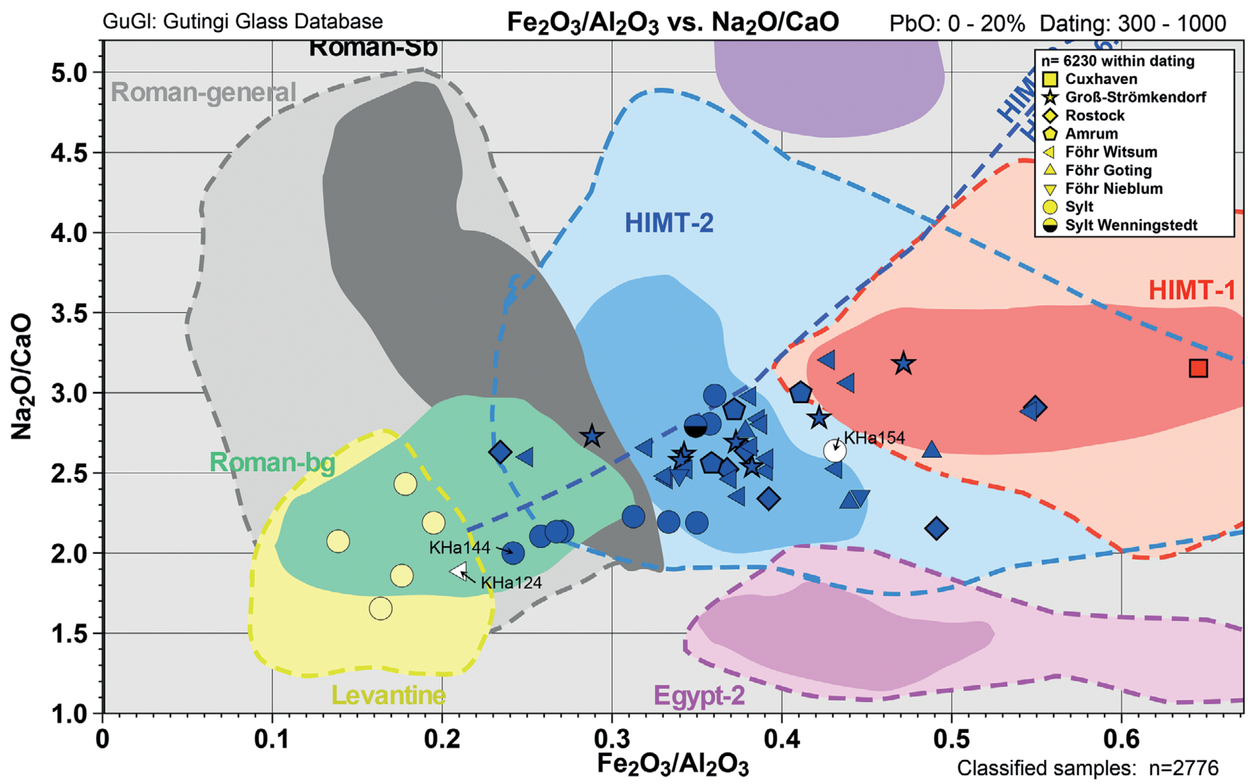


Fig. 13 Variation of glass compositions in the system Fe_2O_3/Al_2O_3 - Na_2O/CaO. **Yellow**: production group Levantine-1. – **Blue**: HIMT-2. – **Red**: HIMT-1. – **Large symbols**: samples from North Sea and Baltic area. – **Medium symbols**: Cologne. – **Small symbols**: other data from literature. Only soda-lime glass samples in the dating period AD 400-900 are included. – (After Kronz 2020, fig. 8).

CONCLUSIONS

Recent settlement excavations on the North Frisian Islands of Föhr and Sylt have vastly expanded the so far quite rare find category of vessel glass in early medieval North Frisia. The glass objects, namely vessel sherds, glass beads and tesserae, from the settlements in Tinnum and Wenningstedt (Sylt) and Witsum, Goting and Nieblum (Föhr) contribute to the questions of the scope of specialized craftsmanship and the role in supra-regional trade networks of these presumed trading sites.

In overview, the glass objects belong to a rather narrow spectrum, both in terms of typology as well as chronology. The larger part of the vessel glass belongs to types of the late 7th and 8th centuries AD. They comprise globular beakers, bowls, possibly large palm cups and elongated palm cups. Funnel beakers form the rather late horizon of finds, ranging in the late 8th to 9th centuries. One claw of a claw beaker from Witsum must be regarded as an old piece, dating to the 7th or even the 6th century. The dating of the assemblages can be established from the typology of regional or locally produced beads, which are found together with the vessel glass. While the Tinnum beads seem to belong to the older phase, possibly in the late 7th or early 8th century, the beads from Wenningstedt, Witsum and from the older layers in Goting show the distinctive characteristics of the mid-8th century. The younger layers in Goting as well as Nieblum belong to the late 8th century, the 9th century in Goting is characterized by imported drawn-cut beads from the Near East[63]. In retrospect, the find material of the 7th/8th centuries forms a quite uniform connection between the different sites, which was to be investigated by the compositional analysis.

In total, 41 glass objects from these sites have been selected for analysis, which confirms a close connectivity across the sites and provides insight into the secondary glass production.

The glass samples are of quite uniform composition, with few exceptions. The large bulk of vessel glass and beads are made of soda-lime glass and belong to the HIMT-2 subtype, one group of samples from Tinnum belong to the Levantine-1 subtype. Only the tessera from Witsum (KHa 124) can be regarded as an original Roman piece of the Roman subtype with Sb as opacifier. The exceptions from the soda-lime glass main type comprise two red glass beads from Tinnum (KHa 152) and Witsum (KHa 122), which belong to a distinctive horizon of imported beads in form of mixed-alkali glass from the Indo-Pacific region and recycled soda-ash glass, traded via the Baltic region in the Early Medieval Period. A piece of flat glass (KHa 149) and a molten glass lump (KHa 150) from Tinnum can be regarded as modern and probably submodern glasses. The complete absence of the late soda-lime glass subtypes Egypt-1 and -2 as well as wood-ash glasses confirm the rather early typological dating of the sampled finds into the 8th century.

All HIMT-2 and Levantine-1 samples show evidence of recycling, which probably happened in the secondary workshops during the production of the original glass vessels. Strong indications of this are the connections between the different compositional groups from Tinnum, which show similarities in base glass but differences in colourants (**fig. 10**, Levantine-1 and HIMT-2, group 1). It is therefore likely, that a rather uniform base glass was re-coloured in separate steps to produce both vibrantly and lighter coloured vessels. The sherd KHa 144, here still classified as HIMT-2 subtype tends in some element ratios towards Levantine-1 glass type. Possibly this is to be interpreted as a mixture and supports the contemporaneous coexistence of both types.

The recycling of these vessel sherds on the North Frisian sites can be confirmed by the analysis. In Tinnum, the optical similarity between the vibrantly coloured vessel sherds and the analogous blue beads is reproduced in the chemical composition (KHa 151, KHa 141 / KHa 148, KHa 153), with minor differences due to contamination. There is also evidence for an intended colouration in the beadmaking process, with strong similarities in base glass between colourless sherds from Tinnum and Wenningstedt with blue-green (Cu) or opaque yellow (Pb, Sn) beads from Tinnum[64]. The fact that the opaque yellow and probably also the opaque green beads from Tinnum could derive from vessel sherds, highlights the absence of tesserae in Tinnum, which are commonly associated with beadmaking in vibrant colours. While tesserae occur in Witsum, an indication for direct sherd-to-bead recycling was also found there in the identical composition of a blue bead and the blue claw beaker (KHa 156 / KHa 165). Furthermore, sherd-recycling with added colourants (Co) is also likely in Witsum (KHa 158, KHa 161 / KHa 160). These connections underline not only the presence of a local bead production on the North Frisian Islands, but also imply advanced technical knowledge such as the manipulation of glass colour versus a more simple, direct recycling.

The glass compositions show several similarities and linkages between the different sites, allowing further remarks on the trade networks within North Frisia. The relative uniform composition of the HIMT-2 vessel glasses and several interlinkages indicate a common origin. Vessels from Witsum (KHa 119, KHa 159, KHa 163, KHa 120) are linked to vessels from Goting (KHa 188) and Nieblum (KHa 118), as is a bead from Nieblum (KHa 117) linked to vessels from Goting (KHa 189, KHa 190). Given the matching archaeological time-frame of all these finds, a shared origin is obvious; not in the sense of all objects deriving from the same glass works or even the same batch, but likely from the same stream of imports.

It is most likely, that the main source of the North Frisian glass can be sought in the Rhineland, as it is indicated by the strong similarities in composition with finds from the Rhineland in general and Cologne in special (**fig. 8-9**). This conclusion is limited by the extent of the comparative database on glass composition data, as it does not contain extensive data from the Anglo-Saxon area, which might also be a possible origin for especially the vibrantly blue glasses from Tinnum and Witsum or the cylindrical beaker from Westerland. [65]

The import of entire glass vessels, as proven by their occurrences in graves, can be grasped from the late 7th century through the 9th century. Their import was most likely accompanied by the import of old Roman tesserae and old glass vessels (as illustrated by the 6th/7th century claw beaker from Witsum) and glass cullet (probably transport waste [66]). This stream of glass imports illuminates the involvement and concentration of the early medieval inhabitants of the North Frisian Islands in a maritime trade route along the North Sea coast between the major trade harbours in Dorestad (Rhine-Meuse-Delta) and Ribe (Southern Jutland) during the late 7th-8th centuries. The vessel glass find material from both emporia is very comparable to the North Frisian finds from a typological perspective [67], albeit comparisons in chemical composition cannot be drawn yet.

The connection with Ribe is still evident through the typology of the bead finds of the mid- to late 8th century, since the beads from Wenningstedt, Witsum and Goting match the products from the Ribe workshops perfectly [68]. The question, whether trade relations with the bead workshops in Ribe determined the style of North Frisian bead makers or that bead makers from Ribe came to the islands as itinerant craftsmen remains open – but both options are conceivable. A connection between North Frisia and the Baltic Sea is indicated by the occurrence of the long-distance imports of the red beads and might have been facilitated through the early trade settlement at Hedeby, but evidence is weak. It is not before the late 8th century, that the local bead production and the import of vessel glass declines in favour of the mass-import of small drawn-cut beads and metal-foiled beads from the Eastern Mediterranean. This change in glass trade can be both observed on the Ribe marketplace [69] and on the stratified workshop-area and the pit-house settlement in Goting [70]. It hints at a general change in the trade networks, in which the declining marketplace of Ribe loses its trade towards the rising emporium of Hedeby, which becomes the major channel for trade between the North Sea and Baltic areas from the 9th century onwards [71]. In that time, the much broader trade network of raw glass, vessel glass and glass beads in Hedeby is characterized by a broad spectrum of glass chemistry [72], which is not to be found in the earlier glass objects in North Frisia.

Notes

1) Majchczack et al. 2018. – Majchczack/Offermann 2018. – Majchczack 2020.

2) Segschneider 2008a. – Majchczack/Segschneider 2015. – Majchczack 2020.

3) The section on the results of the chemical analysis is based on the report by Kronz 2020.

4) Braren 1935. – Kersten/La Baume 1958. – Eisenschmidt 2004.

5) Norddorf, NF LA 127. – Segschneider 2002. The LA-Numbers are the official site designation by the State Archaeological Department of Schleswig-Holstein.

6) Segschneider 2002; 2012.

7) Nebel, NF LA 324. – Segschneider 2002, 128.

8) Segschneider 2018, 74.

9) Jöns 1996, 216.

10) Jankuhn 1958. – Majchczack 2015a.

11) Eisenschmidt 2004.

12) Sylt-Ost Keitum, NF LA 170. – Majchczack in prep.

13) Sylt Ost Morsum, NF LA 82. – Kersten/La Baume 1958, 517 Taf. 152. – Eisenschmidt 2004, 493.

14) Süderende NF LA 47. – Kersten/La Baume 1958, 310 Taf. 115. – Eisenschmidt 2004, 474.

15) Eisenschmidt 2004, Cat.-No. 39.08.

16) Westerland, NF LA 32. – Kersten/La Baume 1958, 632. – Eisenschmidt 2004, 503.

17) Evison 1982; 2000.

18) Westphalen 1999, 122-123.

19) Majchczack 2020, 392.

20) Majchczack 2013; 2020. – Majchczack et al. 2018.

21) Segschneider 2008b.

22) Preliminary reports: Segschneider 2008a, 2008b. – Majchczack/ Segschneider 2015. The full analysis of the early medieval settlement is included in Majchczack 2020, chapter 5.1.

23) Majchczack/Segschneider 2015.

24) Harck (1990, 198-200 Taf. 33) maps the creeks between the Tinnumburg and the (then unknown) settlement but is critical about the navigability; see also Segschneider 2008b and Majchczack 2020, 26-27.

25) Callmer 2007. – Delvaux 2017. – Feveile/Jensen 2006. – Holme Andersen/Sode 2010.

26) Majchczack 2020, 70. 78.

27) Majchczack 2020, 92-95.

28) Majchczack 2020, chapter 5.2.

29) The »blue-white-red« horizon is dated into Phase C at Ribe marketplace, around 725-760: Callmer 1997; 2007. – Feveile/ Jensen 2006. – Delvaux 2017. – Holme Andersen/Sode 2010.

30) Majchczack 2013, 2015b.

31) The results of the 2016 excavation campaign are published in Majchczack 2020, chapter 5.5.

32) The wasp-beads are typical for Phase E on the Ribe marketplace around 780-790. – Callmer 1997. – Holme Andersen/ Sode 2010. – Delvaux 2017.

33) Majchczack 2013, 2015. – Majchczack et al. 2018.

34) The 2013/2014 excavations are partly published in Majchczack et al. 2018, the later excavations are published in Majchczack 2020, chapter 5.3.

35) After Callmer 1997; 2007.

36) A concise summary of the site's topography and research history is given in Majchczack 2014, 2015a; Majchczack et al. 2018 together with preliminary reports of the 2014 excavation; the 2017/2018 excavations are published in Majchczack 2020, chapter 5.4.

37) Majchczack 2020, 193.

38) Majchczack 2020, 189-193.

39) All listed features and their find inventories are published in Majchczack 2020, Volume 2.

40) EPMA: JEOL JXA 8900 (Si, Ti, Al, Fe, Mn, Mg, Ca,Na, P, K, S, Cl, Co, Cu, As, Sr, Sn, Sb, Ba, Pb).

41) ICPMS: Element-2TM, ThermoFisher. The methodology is described in detail by Wedepohl/Simon/Kronz 2011. The complete analysis data will be published elsewhere.

42) Dodt 2016.

43) As discussed by Freestone/Price/Cartwright 2009.

44) Soda-Kalk-Glas, Sodaascheglas and Holzascheglas after Wedepohl 2003.

45) Van Wersch 2016. – Wedepohl/Winkelmann/Hartmann 1997.

46) Sode/Gratuze/Lankton 2015.

47) Sode/Gratuze/Lankton 2015, 330.

48) So-called local model, e. g. Wedepohl 2003.

49) Foy/Nenna 2001; 2003. – Summarized Whitehouse 2003; so-called regional model; see also discussion in Foster/Jackson 2010.

50) Rehren/Brüggler 2020.

51) As claimed by Wedepohl/Hartmann 2000.

52) Freestone 2015.

53) Definitions in Freestone/Wolf/Thirlwall 2005. – Foster/Jackson 2009.

54) Foy et al. 2003.

55) »wHIMT«, Rosenow/Rehren 2014.

56) »HLIMT«, Ceglia et al. 2015.

57) Mirti/Lepora/Sagui 2000. – Mirti et al. 2001. – Foot pieces of green goblets ref.: »CB-10«, »CB-11«, »CB-12«, 7th century and »CB-47«, 8th century.

58) Freestone/Price/Cartwright 2009.

59) In summary, among others, Brems/Degryse 2014. – Freestone 2015. – Paynter/Jackson 2016. – Exemplary for the Rhineland: Rehren/Brüggler 2015.

60) Kronz et al. 2016.

61) See e. g. Wedepohl/Kronz 2012.

62) Gratuze 1988.

63) Majchczack 2020, 234.

64) While the similarities in vessel glass from Wenningstedt and beads from Tinnum are shown by the compositional analysis, a typological link between the distinctive vibrantly coloured beads from Tinnum and Wenningstedt had been missing so far. In 2018 and 2019, after the analysis, new surface finds from Wenningstedt included a vivid turquoise-blue melon-shaped bead and opaque yellow barrel-shaped beads that equal the Tinnum finds in shape and optics (Majchczack 2020, 100).

65) Majchczack 2020, 148. 236.

66) Lund Feveile (2006, 254-255) argues that the vessel sherds on the Ribe marketplace derive from vessels broken during transport to the consumer (secondary waste) and vessels broken during use by the consumer (tertiary waste), but finds no evidence for cullet that was imported directly from the vessel-manufacturing glass workshops (primary waste).

67) Dorestad: Isings 1980, 2010. – Ribe: Feveile 2013. – Lund Feveile 2006.

68) Callmer 2007. – Delvaux 2017. – Holme Andersen / Sode 2010. – Majchczack 2020, 234.

69) Feveile / Jensen 2006. – Delvaux 2017. – Sode / Feveile / Schnell 2010.

70) Majchczack 2020, 289-194.

71) Feveile 2006. – Maixner 2012, 13-19. – Majchczack 2020, 276.

72) Kronz et al. 2016.

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Zusammenfassung

Die nordfriesischen Inseln Föhr, Amrum und Sylt waren wichtiger Bestandteil innerhalb eines frühmittelalterlichen Handelsnetzwerks entlang der Nordseeküste und waren das Hauptuntersuchungsgebiet des Projekts zu den Nordsee-Häfen 2013-2018. Ausgrabungen in den Handelssiedlungen Witsum, Goting und Nieblum auf Föhr ergaben zusammen mit vorherigen Ausgrabungen und Surveys in Tinnum und Wenningstedt auf Sylt eine große Anzahl von Glasobjekten des 7.-10. Jahrhunderts, darunter Glasscherben, Tesserae, Glasperlen und Hinweise auf Perlenherstellung. Eine Auswahl von 41 Glasobjekten, die typologisch in das 7.-8. Jahrhundert zu datieren sind, wurden beprobt und mittels Electron Microprobe und LaICPMS analysiert. Die Analyse zeigt, dass die Mehrheit dieser Objekte zu den Subtypen HIMT-2 und Levantine-1 des Haupttyps Soda-Kalk-Glas gehört. Die relativ geringe Schwankungsbreite der chemischen Glaszusammensetzung zusammen mit mehreren Verbindungen zwischen Gläsern aus verschiedenen Fundorten deutet auf einen gemeinsamen Strom von Glasimporten auf die Inseln, wahrscheinlich aus dem Rheinland, hin. Außerdem konnte die lokale Präsenz von Perlenmachern bestätigt werden, die importierte Scherben und Mosaiksteine als Recyclingmaterial für Glasperlen verwendeten. Höhere Gehalte an bestimmten Spurenelementen deuten eher auf die Verwendung von Glasscherben als auf die Einfuhr von (reinem) Glas aus Primärwerkstätten hin.

Summary

The North Frisian Islands of Föhr, Amrum and Sylt formed an important part within an early medieval trade network along the North Sea coast and were a focus research area in the North Sea Harbour Project in 2013-2018. Excavations in trading settlements in Witsum, Goting and Nieblum on the island of Föhr, together with previous excavations and surveys in Tinnum and Wenningstedt on the island of Sylt, yielded a large number of glass objects of the 7th-10th centuries, such as vessel glass sherds, glass beads, tesserae and evidence for beadmaking. A selection of 41 glass objects, typologically dated into the late 7th-8th centuries, has been sampled for compositional analysis with Electron Microprobe and LaICPMS (Laser ablation Inductively coupled plasma mass spectrometry). The analysis show that the majority of these objects belong to the subtypes HIMT-2 and Levantine-1 of the soda-lime glass main type. A rather

narrow variation of the chemical glass composition with several interlinkages between glasses from different sites indicate a shared stream of glass imports to the islands, probably from the Rhineland. Furthermore, it was possible to confirm the local presence of beadmaking craftsmen, using imported cullet and tesserae as recycling material for glass beads. Higher levels of particular trace elements indicate the use of glass cullet rather than the import of (pure) glass from primary workshops.