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'GLASS PRODUCTION AND TRADE IN THE EARLY ISLAMIC PERSIAN GULF'

by

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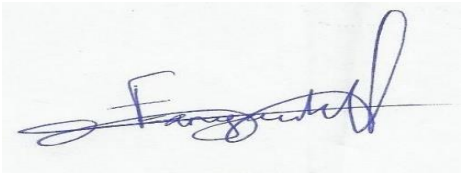
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d) All assistance received has been acknowledged.



Cover Image: Closed folded and flattened rim uncovered during the excavations at Mughaira in the Kuwaiti Bay (photo taken by the author)

ABSTRACT

This thesis aims to provide the first statistically coherent interdisciplinary study of 7th to 10th century AD glass from the Persian Gulf. It is designed to contribute in a new way to the study of production and trade of glass along part of the 'Spice Route'. It will focus on glass excavated in northern Kuwait and in Unguja Ukuu, Africa. The objectives of the thesis are to understand 1) what were the sources of glass in the 7th -9th century AD Persian Gulf, 2) were Baṣra (southern Iraq) and Siraf (southern Iran) early Islamic primary production centers for glass, and 3) what types of early Islamic glass were traded in the Persian Gulf and in Unguja Ukuu, Africa within the context of 'proto-globalization'? Glass production and trade in the early Islamic Persian Gulf (7th to 8th century AD) remains one of the least investigated fields of enquiry in recent scholarship and has become a topic of interest for those seeking to identify primary glass production zones and the geological origins of glass raw materials. There was a time when the glass manufacture was an established industry in the Persian Gulf (Pinder-Wilson,1963:33). The evidence is as near as conclusive as possible and prove that a thriving industry was already flourishing in Egypt, Syria, Iran and Iraq when these lands conquered by Muslims in the course of the 7th century AD (Lamm,1930:496-8;Lamm1935:8;Charleston,1942:217;Saldern,1966:17; Lukeins,1965:198;Hasson,1979:3;Klein,Lloyd,2000:58). Thus far, however, research in the Near East has focused primarily on the origins of Egypt and Syria rather than on Iran and Iraq (Freestone *et al.*,2003;Henderson *et al.*,2004;Henderson *et al.*,2009). As a result, we lack valuable information about the thriving glassmaking industry on Persian soil, whose products met so wide distribution as wide as the Islamic influence at that time and as far as China and Japan. This thesis examines the glass production and the trade during the early Islamic period based on the findings of chemical analysis. Such a study has never been carried out for the Persian Gulf. A main goal of this research is to improve our knowledge of the early sources of glass manufacture in the Persian Gulf, to provide a basis for distinguishing the early Islamic Persian glass made in different parts of the world and to provide direct evidence for its trade.

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CHAPTER 1

INTRODUCTION

1.1 The investigation of glass production and trade in the Early Islamic Persian Gulf

An investigation of glass production and trade in the early Islamic Persian Gulf is given here. The glass industry was already flourishing in Egypt, Syria, Levant, Iran and Iraq when these lands were conquered by Muslims in the course of the 7th century AD (Lamm,1930:496-8;Lamm, 1935:8;Charleston,1942:217;Saldern,1966:17;Lukeins,1965:198;Hasson,1979:3;Klein,Lloyd, 2000:58). The location of this glass industry east of Euphrates is not known for certain. So far, little is known about the origin of the high-quality glass manufactured in Iraq and Iran, as previous research has mainly focused on the west of Euphrates in Egypt, Syria and Levant (Freestone *et al.*,2003;Henderson *et al.*,2004;Henderson *et al.*,2009). Glass and glass vessels must have been produced or worked in the Persian Gulf and traded as far as the East African coast. The main purpose of the thesis is to identify the glass sources, the origin of the vessels and the glass trade along the shores of the Persian Gulf and the East African coast, by chemically analysing 160 glass fragments uncovered at the archaeological sites Kadhima, Mughaira and Shiqaya in the Kuwaiti Bay, and 105 glass fragments uncovered at Unguja Ukuu, Zanzibar on the East African coast (***Figure 1.1.1***). Regarding the glass sources, there is absolutely no evidence of glass working at any of the Kuwaiti sites (Blair,2016:341). Indeed, it is likely that the nearest source of glass and the vessels themselves were the ports of Baṣra or Sīrāf, in close proximity to other Iraqi or Iranian sites east of the Euphrates. The objectives of the thesis are to understand 1) what were the sources of glass in the 7th -9th century AD Persian Gulf, 2) were Başra (southern Iraq) and Siraf (southern Iran) early Islamic primary production centers for glass, and 3) what types of early Islamic glass were traded in the Persian Gulf and in Unguja Ukuu, Africa within the context of 'proto-globalization'?

This thesis will investigate only the first period of the production of Islamic glass when the Islamic world was under the ´Abbāsid and Umayyad caliphates (***Table 1.1***). The production of Islamic glass can be divided into three periods. The first was from the 7th to the 11th centuries AD, the second from the 12th to 15th centuries AD and the third between the 17th and 18th centuries AD (Tait,1991:112). Glass of the first period developed in the context of the cultural legacy of the Eastern Roman Empire and the Partho-Sasanian period of Persia, and was as important as

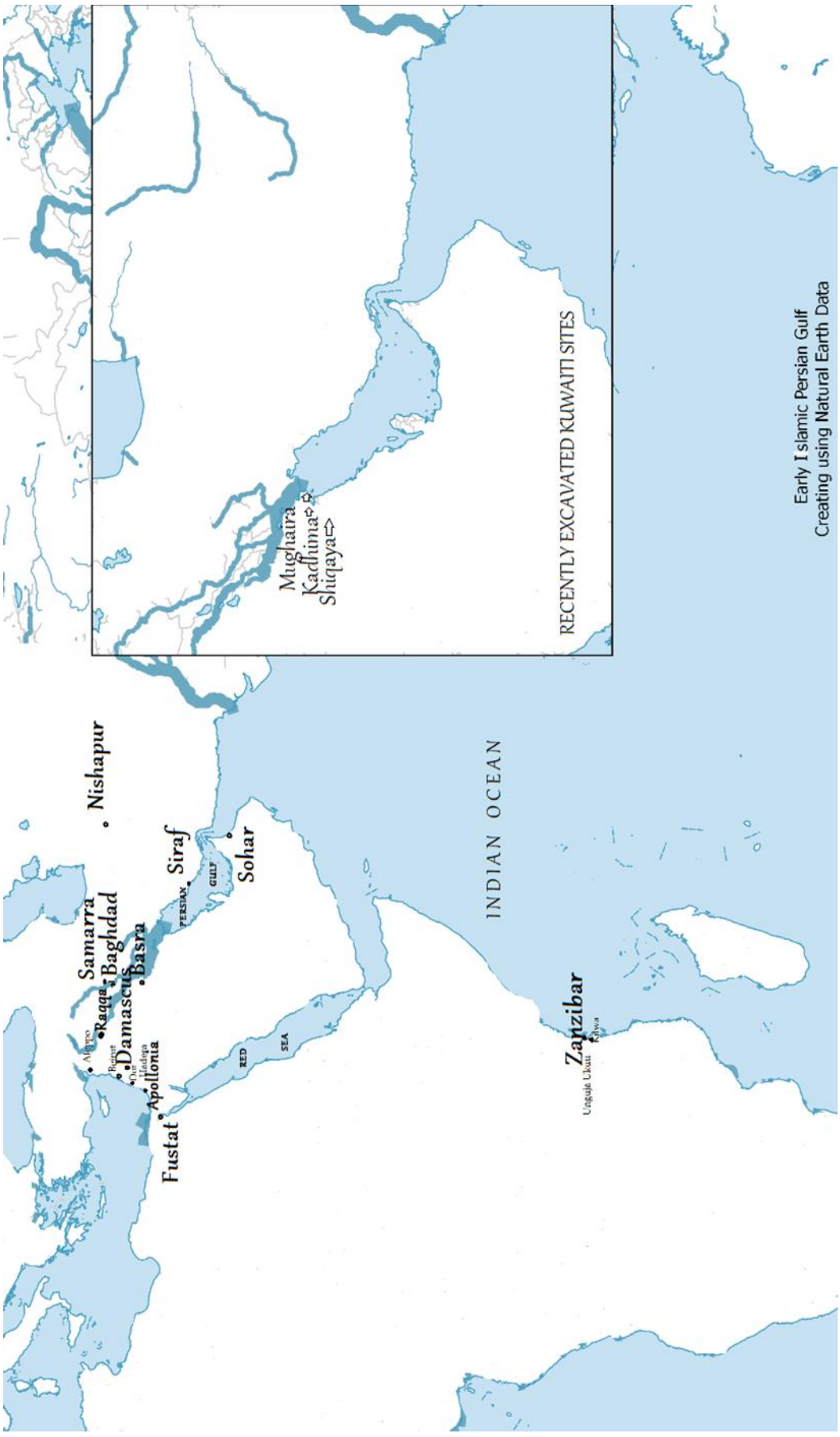


Figure 1.1.1: *The principal sites mentioned in the research.*

Table 1.1: Political periodization

POLITICAL PERIODIZATION		
500	570-632	Prophet Muhammad was born in Mecca.
600	634 639-642 656-661 661-749	Conquest of Iraq and Syria by Muslim armies Conquest of Egypt by Muslim armies Ali caliph **Umayyad Caliphate** rules from Damascus Greater Syria was formed
700	750 776-809	Beginning of ´**Abbāsid Caliphate** Capital at Baghdad The ´Abbāsids occupied Greater Iraq Caliphate of Harun al-Rashid
800	835-892 850 750-1258	´Abbāsid capital moved from Baghdad to Sāmarrā ´Abbāsid Caliphate interrupted in Syria ´Abbāsid Caliphate continued uninterrupted in Baghdad
900	945 969-1171	**Buyids** take control of ´Abbāsid Caliphate Fatimids conquer Egypt and Greater Syria
1000	1040-1194	Seljuks occupied Iran and Anatolia
1100	1171-1250	**Ayyūbid Caliphate** rules from Cairo

that of Rome (Fukai,1977:62). Glassware in the Roman world was mass produced in order to satisfy the needs of the middle-class Islamic society (Tait,1991:112). The high quality Sasanian glassmaking contributed to the development of outstanding glasswork. The ´Abbāsid and Umayyad conquest was in no way detrimental to the continuity of the flourishing glass industries, that continued without interruption into the Islamic period, supplying the new political masters with glassware and adjusting the styles to suit the requirements of those patrons (Hasson,1979:3;Tait,1991:115). This continuity was evident in the many instances where pre-Islamic glassware can hardly be distinguished from the glass produced in the early Islamic period (Lamm,1935:8;Hasson,1979:3;Carboni,2001:15). The Muslim glass artisans used the technical and artistic achievements of the Classical world but struggled to find their own artistic identity until the 9th century AD, when new techniques and forms developed, which gave impetus to the glass industries in Islamic countries (Hasson,1979:3;Carboni,2001:15). The 9th and 10th centuries AD are of great importance, when Islamic glass manufacturing reached its finest point, although glass continued to be produced for daily needs too (Kröger,1995:37). Both decorated and undecorated types were being mass-produced in great numbers and, generally, a high technical level had been reached (Kröger,1995:37).

Any history of glass production and trade in the Persian Gulf will necessarily focus on its main ports, Baṣra and Sīrāf. Başra and Sīrāf were the chief ports connecting the waterways of the Indian Ocean with Baghdad, the centre of the Islamic Empire (Hourani,1995:64). Those ports became important entrepôts, connected to each other and to the mainland; all kinds of commodities, ideas, and ways of thinking were passed through those ports back and forth (Potter, 2009:4). Situated sixty miles away from the Persian Gulf, in an ideal topographical area with roads leading to Syria and the Nejd in the west and Iran in the east, the entrepôt of Baṣra was an important and well-known manufacturing location for lustre-painting on pottery and probably glass(Ettinghausen,1942:7;Mason,Brill,1970:354;Keall,1991;Hallet,1999:79;Giralt,2014:13;Blair,2016:341). The town on the Shatt al Arab in Southern Iraq was less than a week's caravan journey overland from Kadhima, Mughaira and Shiqaya in the Kuwaiti Bay and is likely to have been the immediate source of Kuwaiti glasses, both glass worked and produced there (Blair, 2016:341).

The site of Kadhima, where some of the glass was obtained from, was part of a large coastal region on the western Kuwait shore during the Umayyad and ´Abbāsid period (Almutairi, 2011:322;Blair,2016:356). Kadhima was a well-known trade centre between the north and the south Arabian Peninsula, located a short distance from Baṣra (Almutairi,2011:322). The exact location of the site is still under discussion. The site was settled during the 8th century AD, or

possibly even earlier in the 7th century AD (Almutairi,2011:346,Blair *et al.*,2012:23). Before the 7th century AD, only nomadic groups seem to have interacted with maritime traders frequenting the Kuwait coastline. The trade in the 7th century AD was small in scale and later seems to have developed into a more systematic, large-scale operation (Blair *et al.*,2012:23). The establishment of semi-permanent or permanent settlements along the coastline seems to indicate an increase in trading activity in the late 7th and 8th centuries AD (Blair *et al.*,2012:24). Due to the scarcity of resources, the site probably based its economy on exploiting the maritime and land-based transport routes (Blair *et al.*,2012:24). Some sources suggest that the site was along several trade routes, such as the pilgrim route between Baṣra and Mecca, the sea route from Baṣra that proceeds to Abadan (northwest Iran), Kadhima, Qatar, Dibba and Suhar, the al-Munkadir land route and the Kadhima to al-Yamamah route (Almutairi,2011:326).

The Mughaira region, which spread up to the tip of the Ras as-Subiyah peninsula, was another region in the Kuwaiti Bay from which glass was located (Blair,2016:379). The Mughaira settlement was probably occupied during the mid-7th to late-8th/early-9th century AD, as the ceramic dating evidence and a series of C-14 dates on a large building seem to confirm (Blair, 2016:327). Mughaira represents a vast settlement with some 75 partially upstanding structural features evident within an area of 20 ha., providing the second location for the glass from Kuwait (Blair,2016:327). By the early 9th century AD, Kadhima and Mughaira had been abandoned as had all the settlements along the coastline (Kennet, Al-Duwish,2013:7). The trade was probably diverted elsewhere and one possible place is Shiqaya (Kennet, Al- Duwish, 2013:7). Shiqaya was a large site in Kuwait with unusual plastered buildings (Kennet,Al-Duwish,2013:7). The settlement shows evidence of a great consumption of pottery and chlorite and had close connections with Iraq (Kennet,Al-Duwish,2013:7). During the ʿAbbāsid period, the trade possibly diverted traffic away from the coastal route. The result was that trade along the coast began to decline and trade activities were concentrated in a few sites such as Shiqaya (Kennet, Al-Duwish,2013:8).

The entrepôt of Sīrāf is another candidate for the source of the Kuwaiti glasses in the Persian Gulf between 800-1050 AD (Whitehouse,1968:12;Whitehouse,1970:142;Swan *et al.*,2017:102). Sīrāf was in a strategic position on the north-eastern coast of the Persian Gulf, connecting the ʿAbbāsid world with the wider world of the Indian Ocean trading network (India, Southeast Asia, China, East Africa and the Red Sea). Archaeological evidence points to glass production in Sīrāf with the presence of structures and kilns related to glassworking facilities, while chemical analysis confirms that there must have been a plant ash glass known as 'local' or 'east Persian' glass produced there (Whitehouse,1968:12;Whitehouse,1970:142;Swan *et al.*,2017:102). Glass

from Sīrāf could have travelled northward to the Kuwaiti Bay or to Baṣra to be exchanged with cargo coming from the mainland, or could have been taken up river to Baghdad (Ricks, 1970:343;Hourani,1995:64). Alternatively, diverse glass from Baṣra could have travelled southward to the Kuwaiti Bay or to Sīrāf to be exchanged with cargo coming from the mainland, or the glass could have been loaded onto seagoing ships travelling southward to the East African coast.

The fall of the Umayyads and the rise of the ´Abbāsids resulted in the development of maritime trade (*Table 1.2 & Table 1.3*)(Ricks,1970:343). Early Islamic glass was one product among others such as antimony, rugs, precious stones from Syria (al-Sham), Egypt, India or the Far East, pearls, cotton, linen, woven fabric, wool, perfume, horses, carpets, pottery that was traded during the 7th and 8th century AD by merchants from the Persian Gulf all the way to China and Africa (Daryaee,2003:3). Until now, questions relating to the extent of the glass trade from the Persian Gulf and its importance in the early Islamic period have remained unanswered. The increased archaeological research in Southeast Asia, China, and Africa point out that many Islamic glass vessels must have been traded from Başra and Sīrāf either as a local product or as a product carried from other places. Many glass artefacts have been found at sites with which the above ports had connections. Unguja Ukuu on the East African coast was one of the sites where many Islamic glass vessels have found. Located on the Unguja island, the town was an important island emporium for ships carrying merchandise to the East African coast from the Persian Gulf ports such as Baṣra and Sīrāf and the Indian Ocean rim countries (Chittick,1966:161;Blair,2016:248). Unguja Ukuu was probably founded during the 7th or even the 8th century AD, even though an earlier date has been proposed (500 AD) and flourished during the 9th century AD (Blair 2016:251). Ceramic and glass imports from outside East Africa were observed at the site (Blair,2016:249). The numerous fragments of Syrian and Arabian glass, turquoise-glazed Sasanian-Islamic glazed pottery, and Chinese ceramic stoneware give a clear indication of the importance of Unguja Ukuu's trade with the Indian Ocean sites (Blair,2016:251). The examination of glass finds by Andrew Blair proved to be very helpful. Blair shows that the best parallel for Unguja Ukuu glasses can be found in the Kuwaiti sites, Kadhima, Mughaira and Shiqaya along the Persian Gulf shore (Blair,2016:252). Purpose of the thesis is to chemical analyse the early Islamic glass recovered in excavations at Unguja Ukuu to determine glass sources and check whether Baṣra and Sīrāf were closely allied with glass trade with East African coast.

Table 1.2: Chronological order with notes of trade.

CHRONOLOGICAL ORDER WITH NOTES OF TRADE			
600	700	800	
600	**ca 700**	**ca 800**	
The rise of Islam	Rapid spread of Islam along established trade routes	Given the increasing role of Arab and Persians merchants community was formed in China	
The northern and eastern desert caravan routes made up over a thousand camels carry goods as gold become instrumental in the spread of Islam.			
600-900	**700**	**860**	
Expansion of Indian Ocean Trade	Shanga on the Pate island on East African coast was occupied Imports of pottery and glass, mainly from the Persian Gulf found at Shanga	Chinese texts mention Persian Gulf and Somali coast, Zanzibar and Madagascar	Madagascar.
Muslims trade in the west and Chinese in the east			
Muslim colonies along the Indian coast			
660	**708-1494**	**868**	
Islam spreads from Spain to al-Sind	Egypt manufactures glass weights as to check accuracy of gold, silver and copper coins	Zanj rebellion Basra taken Al-Jahiz first mention to Unguja Ukuu	
		883	
681-907		Zanj revolt crushed seriously affected trade in the region	
T'ang Dynasty			
The T'ang dynasty led to the creation of new consumer demand			

Table 1.3: Chronological order with notes of trade.

CHRONOLOGICAL ORDER WITH NOTES OF TRADE

900	late900	1000	1100
906	969	1030	1100-1166
Decline and fall of the T'ang Dynasty	The **shift** of the maritime **route** from the Persian Gulf to Red Sea	Al-Mas'udi visits Ceylon and writes that traders from Siraf and Oman had made voyages there	The Moroccan-born geographer al- Idrisi visits Ceylon and write his famous geography.
The immediate decline of trade with China follows the collapse of the T'ang Dynasty	The Cairo Genizah texts written with replete with references to **trade**		
916	977		
The well-travelled Baghdad Arab, al-Mas'udi visits northern East Africa providing an account of the Swahili at that time	On 17 June Siraf damaged by earthquake Persian Gulf trade was affected		
961			
The scholar and scientist Al-Biruni visits Ceylon			
969	late 900s		
Fatimid Caliphate founded Cairo in Egypt	Following the commercial decline many early settlements begun to decline at the East Africna coast		

During the latter part of the 9th century AD, changes in the shores of the Persian Gulf coast and the East African coast were observed. The importance of the port of Baṣra declined, and the city and port of Sīrāf gradually replaced Baṣra. Sīrāf was the most important entrepôt during the 10th century AD (Whitehouse,1970;Ricks,1970:343). Sīrāf's merchants were actively engaged in both the Red Sea and India-China trade until the 10th century AD (Whitehouse,1970:142). Unguja Ukuu also saw changes over this period. By the 10th century AD, the emporium had been more or less total abandoned and trade declined (Blair,2016:252). Later, Sīrāf had suffered several disasters and the earthquake of AD 977 was thought to have destroyed the port (Whitehouse,1970:142). The reason for the decline is still unknown. The archaeological and historical evidence suggests that the Persian Gulf merchants and traders continued to come to Sīrāf to refit their ships and seek shelter on their way from Kirman to Mahruban (Ricks,1970:352). The most significant event for Sīrāf was the rise of Kish, a small island in the lower Persian Gulf, and the migration of Sīrāf's mercantile population to that island following the sporadic break-down of security along the overland routes from Shiraz, the ambitions of princely states along the Gulf's coasts, and the weakening of the 'ʿAbbāsid Caliphate in Baghdad during the 11th and 12th centuries AD. These were among the reasons for the city's decline (Whitehouse,1970:142;Ricks,1970:352).

1.2 Aims and objectives of the project

This thesis aims to provide the first statistically coherent interdisciplinary study of the 7th - 10th century AD glass from the Persian Gulf and the East African coast. It is designed to contribute in a new way to the study of production and trade of glass along part of the 'Spice Route'. The understanding of glass production and trade have relied on chemical characterisation of 265 glass fragments. In more detail, 160 glass fragments from three particular archaeological sites from the northern coastline of Kuwait Bay, Kadhima, Mughaira and Shiqaya and 105 glass fragments from Unguja Ukuu, Zanzibar will be analysed for major and minor elements. The chemical analysis will reveal the composition of a variety of open and closed or semi-open vessels. Chemical composition can provide a range of information about raw materials, glass technology production and the provenance of the early Islamic glass (Henderson,2003:109,Henderson *et al.*,2005;Degryse *et al.*,2009:15;Schibille,2011:5;Henderson,2016:39). Chemical analysis results will suggest which regions produced the various Kuwaiti and Unguja Ukuu glasses. From this, trade relations and routes that connected the Persian Gulf with the other Islamic places and the East African coast can be reconstructed. The compositional data of the thesis are then used to answer the major research questions of this thesis.

The major research questions of this thesis are:

- what were the sources of glass in the early Islamic Persian Gulf and in Unguja Ukuu on the East African coast?
- were Baṣra (southern Iraq) and Sīrāf (southern Iran) early Islamic primary production centres for glass?
- what types of glass were traded in the Persian Gulf and in Unguja Ukuu within the context of proto-globalization?

The first question to be answered is which are the likely sources of the Kuwaiti and Unguja Ukuu glasses. The understanding of the glass sources relies on the comparison of the glass compositional data of this thesis with data of glass from the major production centres. The scientific analyses had demonstrated at least five, six, seven types of glass made of raw materials from a range of sources and with varying impurities (Henderson,2016:39). The major element analyses recognised meaningful production groups in the Islamic world (Schibille,2011:5). Multivariate statistical analysis of compositional data for lumps of raw glass from shipwrecks and

workshops along with typologically well characterized vessels has allowed Foy and his colleagues to identify 10 distinctive low magnesia glass groups in use in the Mediterranean region in the first millennium AD, on the basis of their major element composition (Foy *et al.*,2000,2003). Each group is assumed to relate to a primary production centre, although such a centre may consist of more than one factory in a single region.

Trace elements analyses refined our understanding of those major production centres (Schibille,2011:5). Using LAICPMS early Islamic glass from the Middle East was analyzed and the trace analyses show spate production zones in al-Raqqa (northern Syria), Cairo, Beirut and Damascus (Henderson,2016:38). The isotopic analysis provided new insights about the circulation of the raw glass material (Freestone,2006:201;Degryse,Shortland,2009:135;Degryse *et al.*,2010:83;Schibille,2011:5;Brems *et al.*,2014:51;Henderson,2016:25). Isotopes can distinguish between different sources of the main glass constituents (Freestone *et al.*,2003:19;Henderson *et al.*,2005:665;Leslie *et al.*,2006). The most discriminatory are strontium and neodymium isotope signature and provide reliable means of distinguishing between the sources of plant ash glass raw materials (Freestone *et al.*,2003:19;Henderson *et al.*, 2005:665;Freestone,2005: 008.1.1;Henderson,2016:25). All the available major, minor and trace elements published results from early Islamic glasses will be used in this thesis to be compared with our major and minor elements results to identify the Kuwaiti and Unguja Ukuu glasses. It is possible to identify in the Persian Gulf area different sources of raw materials.

From a general perspective, if major and minor element analysis of the Kuwaiti and Unguja Ukuu glasses identify the composition of glass from major glassmaking centres then we should search there for the sources of the glasses. However, if it recognized a distinctive primary glass source which is differentiated from primary production centres, especially from the Iraqi and Iranian sites (Baghdad, Sāmarrā, Ctesiphon, Nishapur) then it means that we have to search for a new production centre probably in the Persian Gulf. If the amount of glasses of the new source is sufficient enough then the potential for the understanding of glass production in the Persian Gulf appears to be high. Furthermore, if localised production of glass can be recognized, as there is no evidence of primary glass production at any of the Kuwaiti sites, we should then search the nearest source of glass at the ports of Baṣra and Sīrāf.

The second question is whether Baṣra (southern Iraq) and Sīrāf were early Islamic primary production centres for the Kuwaiti glasses. The archaeological evidence suggests that glass uncovered from Kadhima, Mughaira and Shiqaya must have travelled from Baṣra, which was probably an important glassworking or glassmaking centre but also a glass trade centre during the

´Abbāsid period. Baṣra, located far up the Shatt al-Arab river, probably constituted a significant market for glass, but its main function must have been to move glass from the interior to the Indian Ocean and the wider world. Our knowledge of the history of glass production in Baṣra is still sparse, as excavations have never been undertaken there. Thus, there are no available compositional data from Baṣra. But if the new analytical data of the current thesis will identify a primary glass source east of Euphrates that is differentiated from other important Iraqi and Iranian sites (Baghdad, Sāmarrā, Ctesiphon, Nishapur) then we should search the source either to Baṣra either to Sīrāf. The discussion will mainly focus on the available compositional data from Sīrāf. Those compositional data will be compared with compositional data from Kadhima, Mughaira, Shiqaya and Unguja Ukuu. The comparison is then used to examine whether the 'local' or 'east Persian' plant-ash glass produced in Sīrāf can be recognized in the Kuwait Bay.

The third question is related with which types of open and closed or semi-open vessels were produced from imported or local glass in the Persian Gulf and traded on the East African coast. A variety of simple in form and type fragments of vessels will be subject to chemical analysis. Components of the early Islamic tradition, such as fragments bearing scratch-engraving, pinched, cane mosaic and trailed decoration, although rare will be also analysed. The compositional data of the Kuwaiti and Unguja Ukuu glasses will then be compared with data from other Islamic sites, especially with specific sub-regional production hubs that major, minor and trace element analysis, conducted by Henderson and his colleagues, shows that are correlated with specific types of vessels with diagnostic decoration (Henderson *et al.*,2016:134). This comparison will reveal if there is a correlation between the chemical composition and typology and if Kuwaiti and Unguja Ukuu glasses and types can be related either with some sub-regional hubs or with localised production. Such a study has, so far, never been carried out in Iran/Iraq, and we hope that this study may contribute significantly to our knowledge.

When we try to trace which specific types produced at specific workshops east of Euphrates, a number of difficulties are encountered. Andrew Blair conducted a typological analysis of early Islamic glass from the north shore of the Persian Gulf and from Unguja Ukuu. An important contribution of Blair's typological analysis was the demonstration of similarity between open and closed or semi-open types of glass from Kadhima, Mughaira and Shiqaya with glass from Unguja Ukuu on the East African coast. But due to the high level of standardisation, Blair was not able to identify the sources of those open and closed or semi-open types of glass and the places that were involved in their trade with the Kuwaiti sites and with Unguja Ukuu. The difficulties that Blair encountered were not surprising. Carl Johan Lamm studied and published on early Islamic

glass in the 1930s, and proposed a number of difficulties associated with the origins of the Islamic glass (Godwin,1929:33;Lamm,1935:8). In 1935 Lamm writes in his book 'Glass from Iran':

"*However, although Ktesiphon, the Madain of the Moslems, is situated outside the borders of present Iran, its art was essentially Persian, and the Early Islamic Art affords signs of an almost equally striking correspondence between the arts of Iraq and Iran, of which fact evidence of special value is obtained by comparing pottery and glass excavated at Susa, with corresponding objects found in Sāmarrā. For this reason, in some cases, it is almost impossible to make a definite distinction between the glass produced in these two countries, in Sasanian and Early Islamic time still is impossible and which forms and types were imported.*" (Lamm,1935: 8).

Alex von Saldern has highlighted that 80% or more of the vessels and decorative patterns of the early Islamic glass are identical in Egypt, Syria, Iraq and Iran and that the local peculiarities are rarely noticeable (Price,Worrell,2003:156). The insignificant regional variation is an important difficulty of the current research. Typological analysis conducted by Andrew Blair demonstrates a wide range of potential origins for the Kuwaiti and Unguja Ukuu glasses with Baṣra to appear as the best source for the Kuwaiti glasses. But through typological analysis, it was not possible to be answered the question from which places the glasses were traded. This thesis will offer the first attempt to verify the origins of the Kuwaiti and Unguja Ukuu glasses in that 'golden age' of Persian Gulf traders providing a window on trade (***Figure 1.2.1***). Early Islamic glass could have travelled from the hinterland of the ´Abbāsid Empire and the foreland of Başra and Sīrāf's ports until Unguja Ukuu. The chemical composition of the glasses compared with compositions of glasses from well-known production centres can demonstrate whether glasses were traded from the well- known production centres to the Persian Gulf and then to Unguja Ukuu or whether they were locally produced in the Persian Gulf and then traded in the wider Indian Ocean.

The success of the thesis is to identify a new glass source in the Persian Gulf. The new analytical data of the current thesis will be first compared with the analytical data from Sīrāf, as there we have a clearer understanding of glass production in the Persian Gulf. The new evidence points a local production in Sīrāf. If the comparison shows a new source that is not related with local production in Sīrāf or with other Iranian (Nishapur) or Iraqi (Baghdad, Sāmarrā, Ctesiphon) sites then the discussion will mainly focus on Başra. If a new source, related to Baṣra or other than Sīrāf, Nishapur, Baghdad, Sāmarrā, Ctesiphon sites, will be recognised then we will compare the new source compositional data with the available published data from all the Islamic world, the East African coast, Southeast Asia and China. With these considerations in mind, the

thesis will contribute to models for trade and trading circuits that traded the glasses in the wider Indian Ocean.



Figure.1.2.1: *Trading ports and cities 681-1500 AD.*

1.3 Methodology

The understanding of glass production and trade have relied on chemical characterisation of 160 glass fragments from Kadhima, Mughaira and Shiqaya and 105 glass fragments from Unguja Ukuu, Zanzibar. This amount of samples is statistically sufficient for characterising the glass from the Persian Gulf and the East African coast. This thesis will present high resolution chemical analyses combined with two techniques for high accuracy to analyse decorated or undecorated glass fragments of various types of open and closed or semi-open vessels encountered in Kuwait and Zanzibar, which will undoubtedly prove of great value and interest. The chemical analysis is intended to be seen as a definitive characterisation of the glasses from the sites represented; that means that chemical analysis results will prove to be very useful.

It is hoped that the analysis will answer questions related to the sources of glass and its long distance trade in the wider Indian Ocean. The Kuwaiti samples will be analysed using the following analytical techniques: a JEOL JXA-8200 electron microprobe system (EPMA) with four wavelength-dispersive for the determination of the major and minor elements, and a Scanning Electron Microscopy (SEM) in the Nanoscale and microscale centre at the University of Nottingham for the determination of the major and minor elements. The Unguja Ukuu samples will be analysed using a Cameca SX100 that operates from a SUN workstation running Solaris 2 in the Environment, Earth and Ecosystem Sciences at The Open University.

1.4 Synopsis of the thesis

This thesis deals effectively, in terms of analysis, with the subject of glass production and trade in a particular geographical area, in the Persian Gulf. The introduction provides a clear agreement for why the glass production and trade in the early Islamic Persian Gulf needs an investigation and creates the opportunities for a thorough investigation. The following chapters provide a brief overview of glass production and trade in the Islamic lands between the 7th and 11th AD with a way as to prepare the reader to understand a possible local production and trade in the Persian Gulf. Purpose of the two chapters is to present all the available philological and archaeological evidence about early Islamic glass production and trade combined with a number of chemical analysis studies of early Islamic glasses as to not leave the reader wanting more in terms of

analysis. The thesis then move on the following chapters into the description of the studied material and the excavations recovered from. Furthermore, the chapters describe the methods used for major and minor element analysis of the studied material to examine whether local production and trade took place in the Persian Gulf. The last chapters present the new compositional data compared with the published compositional data from other Islamic places. This knowledge is then be used to provide a window on glass production and on an important facet of Persian Gulf trade with the East African coast.

Chapter 1: The main purpose of the first chapter is to show how this thesis has been facilitated by the fact that the history of glass production and trade in the early Islamic Persian Gulf is still largely unknown. The introduction explains how the chief ports Başra and Sīrāf in the Persian Gulf connecting the waterways of the Indian Ocean with Baghdad, the centre of the Islamic Empire could have been involved in the production of glass and trade (Hourani,1995:64). Then points that a clear vision of glass production and trade can be formulated by a sufficient body of compositional data from three archaeological sites in the Persian Gulf, Kadhima, Mughaira and Shiqaya. After presenting the Kuwaiti sites points that compositional data from Unguja Ukuu, Zanzibar can be also used to reveal the glass trade between the ports of Başra and Sīrāf with the East African coast. Chapter 1 clearly outlines the purposes of the thesis and how chemical analysis of 260 glasses, dated between the 7th and 11th centuries AD, can illuminate us if the glass was produced at Baṣra and Sīrāf ports and traded on the East African coast.

Chapter 2: Chapter 2 focus on the history of early Islamic glass production. The brief overview of glass production in the first millennium AD given here will benefit the readers who are not familiar with glass production, its organization in early Islamic society and its division. It describes how scientific analysis is leading to an improved understanding of glass production as few literary medieval documents exist that give information on the manufacture of glass in early Islamic times. Then explore a key theme in the early Islamic glass production which is the division of production into primary workshops that producing raw glass and secondary workshops in which the raw glass was fused to fabricate vessels. The concept of a division of production will help the reader to understand our interpretation of the new analytical data coming from Unguja Ukuu and the Kuwaiti sites, explaining that glass compositions reflect predominantly the primary glassmaking sources, rather than the secondary workshops in which the objects were made (e.g. Nenna *et al.,*1997;Foy *et al.*,2000;Freestone *et al.*,2000,2002a). The chapter then moves on the description of how the actual reconstruction of the early Islamic glass production came through

the discoveries of glass finds emerging from the controlled archaeological excavations since 1930, and of large glassmaking installations uncovered in Egypt, Levant and Syria which were not associated with glass working, but represented the melting of raw materials to produce glass (Sode,Kock: 2001;Freestone *et al.*,2002:167;Baker 2003:167;Freestone,2006:204;Degryse *et al.*, 2009:2;Degryse,Shortland,2009:135;Rehren,Freestone,2015:233). In the end, the chapter will unpack what the chemical analysis results of specific types and forms of vessels and their decoration combined with the archaeological evidence can illuminate us about regional traditions of specialist glass ateliers. This body of data will help the reader to understand how specific types and forms of the Kuwaiti and Unguja Ukuu vessels and their decoration are associated with specialist glass ateliers.

Chapter 3: Chapter 3 provides an examination of Persian Gulf glass trade during the 7th and 11th centuries AD focusing on its main ports Baṣra and Sīrāf. It explains of how and why long-distance glass trade from those Persian Gulf ports was invisible in the medieval sources. Then moves on to offer an overview of the Persian Gulf trade with Southeast Asia and China, using all the information coming from controlled archaeological excavations combined with chemical analysis studies of early Islamic glasses that have been found in sites in Southeast Asia and China, with which Başra and Sīrāf ports had connections. In the end, the chapter addresses the Persian Gulf trade with the East African coast and especially the trade relations of Başra and Sīrāf ports with Unguja Ukuu site. Chapter 3 will help the reader to understand trade connections and how early Islamic glasses, especially glasses form Kadhima, Mughaira, Shiqaya and Unguja Ukuu, either produced or worked or traded from the Islamic lands to Baṣra and Sīrāf ports could have travelled in the wider Indian Ocean.

Chapter 4: Chapter 4 provides analytical information about the archaeological excavations of Kadhima, Mughaira, Shiqaya, Siraf and Unguja Ukuu. The chapter describes the contexts where the glasses recovered from. The description of the contexts will provide the reader insights into the site's history as well as into trade.

Chapter 5: Chapter 5 will present the methods of chemical analysis that will be used to verify the chemical composition of the studied material to search the sources of the glasses and their trade. Then will follow an analytical table with information about the studied material and tables with information about the reference materials. Chapter 5 also describes 260 glass fragments found in excavations at Kadhima, Mughaira, Shiqaya and Unguja Ukuu.

Chapter 6: Chapter 6 lays the foundation for this thesis. It reveals the chemical composition of 265 early Islamic glasses found in Kadhima, Mughaira, Shiqaya and Unguja Ukuu, based on EPMA and SEM analysis. It describes how and why each glass is grouped by type and variation. Then it presents the comparisons of the new compositional data of Kuwaiti and Unguja Ukuu glasses with compositional data from other early Islamic sites to identify the sources of the glasses.

Chapter 7: Chapter 7 is an interpretation of chemical analysis results and discussion of the chemical composition of the glasses as to illuminate the reader about the sources of the Kuwaiti and Unguja Ukuu glasses and the trading circuits that carried them from the Islamic lands to the Persian Gulf and to the East African coast. In addition, the chapter highlights the evidence of a new plant ash group, outlines its compositional characteristic and provides some indicators as its possible origin east of the Euphrates in Iraq.

Chapter 8: Chapter 8 discusses how the results of the chemical analysis of 260 glass fragments from Kadhima, Mughaira, Shiqaya and Unguja Ukuu, can determine the glass sources and trade. It explores different interpretations of the results and unpacks what compositional data may be able to tell us about glass production in the early Islamic Persian Gulf and the Persian Gulf's glass trade with the East African coast. Then Chapter 7 provides a number of key themes in the study of glass production and trade in the early Islamic Persian Gulf and on the East African coast that still need further investigation.

CHAPTER 2

THE EARLY ISLAMIC GLASS PRODUCTION

2.1 Glass production in the Early Islamic world

After the death of Abul' l-Qasim Muhammad (ibn Abdallah, ibn Abd al-Muttalib, ibn Hashim) in AD 632 the religion of Islam dominated the Arabian Peninsula and became the basis of Arab unity, developing eventually into the Arab or Islamic Empire (Klein,Lloyd,2000:58;Hess, 2004:1). The political unification of western Asia and the southern shores of the Mediterranean under a single ruler resulted in the creation of a new unitary civilization (Pinder-Wilson,1968:58; Lukeins,1965:199;Klein *et al.*,2000:58). The new Islamic civilization which arose was an obvious sign of a sophisticated society (Hess,2004:38;Henderson,2013:254). A number of academies, schools, libraries, and observatories were established; great advances occurred in research, literature, poetry, chemistry and engineering (Hess,2004:2;Henderson,2016:23). Within that sophisticated society every aspect of art was supported and a new manner of art was observed (Hess,2004:2,38). Crafts and arts, such as glassmaking and glassworking, were developed with new scientific advancements (Hess,2004:2). According to the renowned philosopher and historian, Ibn Khaldun (AD 1406) (Khaldun,1967:302), cited in Baker (Baker,2004:10): "*Activities required for luxury customs and conditions exist only in cities of a highly developed culture ... Among such activities are those of glassblowers, goldsmiths, perfumers, cooks, coppersmiths, biscuit makers, ... weavers of brocades, and the like ... Such crafts will exist in a particular city but not in others*". Early Islamic glass production is the core of subchapter 2.1. This chapter attempts to present the available philological evidence about glass production and its organization in early Islamic society.

The beginning of early Islamic glass production is hard to date precisely, as it seems to have evolved gradually during the first centuries of Islamic rulers but generally did not exist earlier than the 8th century AD (Hess,2004:1,38). The centuries that follow the 8th century AD were the most productive in glassmaking. They were characterized by cities that were thriving artistically and craftsmen that were at the height of their power (Lukens,1965:199; Kröger,1995:33). Before the advent of Islam, the glassworkshops of the Eastern Mediterranean and Egypt were the most innovative (Lamm,1930:96-8;Lamm,1935:8;Charleston,1942:217; Saldern,1966:17;Lukens,1965:198;Hasson,1979:3;Jenkins,1986:11;Klein *et al.*,2000:58;

Carboni,2000:15). The late antique tradition was their inspiration. The new rulers wanted to incorporate the art of those glasshouses within its walls, as that incorporation could convey to the observer the notion of status, power, prosperity and magnificence (Baker,2004:4). The Arabs inherited the classic forms from those glasshouses (Madden,1975:423;Carboni,2000:15). Muslim and non-Muslim glassmakers based on the methods of the earlier traditions were extraordinarily creative and brought the craft to new artistic heights (Fukai,1977:62;Carboni, 2006:297;Goldstein,2005:11,Henderson,2013:260). The early Islamic glassworkers began to experiment with new methods and finally developed a unique style of their own and inaugurated a period of innovation which culminated in the superb and quintessentially lustre-painted and relief-cut vessels (***Figure 2.1.1***,Tait,1991:125;Harden *et al.*,1968:98;Jenkins,1986:11;Hess, 2004:38; Henderson,2005;Henderson,2008;Henderson,2016:23).

The early Islamic glass was of great artistic merit (Lukens,1965:198,Ettinghausen,1975:5; Goldstein,2005:11;Henderson,2013:260). Goblets, bottles and cups expertly carved with animalistic and geometric designs in intaglio and high relief are examples of the high level of craftsmanship (Saldern,1966:17). Ingenious new techniques were invented. Vessel forms, easily identified as being Islamic, such as the relief-cut decoration, started to be produced at the 9th century AD (Henderson,2013:258). Early men of science in experimentation were involved in the above industries (Henderson,2016:23). New scientific development occurred also in glassmaking production(Lukens,1965:198;Ettinghausen,1975:5;Hess,2004:2;Goldstein,2005:11 Henderson,2005;Henderson,2008;Henderson,2013:260). The full replacement of soda lime to plant ash as the main alkali flux source was among those technological innovations that occurred at some point during the 9th century AD (Lukens,1965:198;Ettinghausen,1975:5;Hess,2004:2; Goldstein,2005:11;Barkoudah,Henderson,2006: 297;Henderson, McLoughlin, Mcphail,2004; Kato,Nakai,Shindo,2009;Henderson,2013:260; Lauwers,2007:55).

After the advent of Islam, Jewish glassmakers continued to blow glass in the Levantine area and to make vessels for Islamic, Byzantine and Jewish markets (Carboni,2000:15;Henderson,2013: 260). Whether the artisans were only Jewish or whether some glassmakers converted to Islam it is impossible to know (Carboni,2000:15). Benjamin of Tuleda, about AD 1167, as cited in Wright (Wright,1848) and in Carboni *et al.* (Carboni *et al.*,2003:145), during his travel from Europe to Central Asia, encountered ten Jews or better yet ten Jewish families involved glassmaking in Antioch. The reports of the Spanish traveller that were frequently quoted in works on the history of glassmaking also refer to the fact that local Jewish people must have been involved both in shipping and glassmaking in Tyre (Carboni *et al.*,2003:145). Benjamin seems



Figure 2.1.1: *Lustre-painted glass of Fatimid Egypt (Tait,1991:125).*

to have visited Tyre about AD 1166 and 1167 (Carboni *et al.*,2003:145). Jews, noted Benjamin, had sea-going vessels (Carboni *et al.*,2003:145). Jews also produced the fine glass called "glass of Tyre" which is highly prized but it is still uncertain if local Jews were involved in glassmaking (Carboni *et al.*,2003:145). Jewish documents, generally dated 1016-1240, found in a Geniza synagogue, Cairo show that Jews in the Islamic world shared glass facilities with Muslims and others of different faiths (Baker,2004:11). According to the Maimonides, a Muslim and a Jewish glassmaker could work together and divide the profits (Baker,2004:11). The profits of glassmaking from production on Friday, when the Muslim absented himself from work, went to the Jewish glassmaker, and vice versa profits from the Saturday working (Baker,2004:11). Jews, Muslims, Christians or paragons are likely to have been involved in glassmaking in al-Raqqa, Syria as the multicultural input to glass production show (Henderson,2013:269).

Medieval Arabic literature, especially the work of geographers, philosophers, poets and commentators, does not provide much specialist information about glassmaking, as the writers were interested mainly in other matters (Baker,2004:12). Medieval written sources about the art of making coloured or colourless glass are few because the art of making glass was kept as a secret of the trade for many centuries until the middle of the 19th century (Turner,1956:298;Baker, 2004:12). The reason that kept the art precious and secretive are clear and justified (Turner,1956:298). The early Islamic glassmakers were using materials available in nature and

glass was quite easy to make (Turner,1956:298). After a lot of experiments, trials and errors in an effort to make a good quality glass, the traditional formulas were also often jealously guarded (Turner,1956:298;Hasson,1979:3). Only very few families of glassmakers knew the secret of how to fuse the raw materials and had the technical skills (Sode,Kock,2001:155). The art was transmitted from father to son and was guarded throughout generations (Sode, Kock, 2001:155, Carboni,2006:298). During the 9th century AD, the writer al-Jabiz (d.c 868 CE) (al-Jahid,1997:39), Khalid b. Yazid of Baghdad, cited in Baker (Baker,2004:12), promised to reveal the secrets of manufacturing materials such as "*the melting of marble, making of mosaic...., manufacture of fir `awni glass and the process of sublimation in the way it should be done*", only before his death. But the actual reconstruction of the early Islamic glass production came through the discoveries of glass finds emerging from the controlled archaeological excavations since 1930 and of large glassmaking installations uncovered in Egypt, Levant and Syria which were not associated with glass working, but represented the melting of raw materials to produce glass (Sode,Kock: 2001;Freestone *et al.*,2002:167;Baker 2003:167;Freestone,2006:204;Degryse *et al.*, 2009:2;Degryse,Shortland,2009:135;Rehren,Freestone,2015:233).

2.2 The raw materials and scientific analysis

The three basic components of all the early Islamic glass were sand, soda and lime (Turner, 1956:296;Biek,Bayley,1979:2;Sawada *et al.*,2003:178;Henderson et.al.,2005:665;Goldstein, 2005:11;Goldstein,2005:11;Freestone,2005:008.1.4.;Freestone,2006:201). Powdered quartz or sand (SiO_2) was the main component (Biek,Bayley,1979:2;Henderson,2003:112;Henderson et.al.,2005:665). Present evidence from analyses of plant ash glass from al-Raqqa, Syria, shows the use of crushed quartz pebbles as a silica source in the Islamic production (Henderson *et al.*, 2005; Freestone,2006:208). Quartzite pebbles were probably collected with some care from river beds or the sea. Pebbles in fact were very hard and brittle. For that reason, they were used by the glassmakers after having been ground to a powder. In AD 990 al-Biruni (al-Biruni,1989:379), cited in Henderson (Henderson,2013:264) in his description of lead-rich glaze mentioned the use of flint as a silica source and goes to say that '*marwat*' are '*white stones from which fire can be struck*'. The last decade's primitive glass factories in Iran used pebbles in the production of faience and glazes (Oppenheim,1970:111). There are certain atomic groupings, of which SiO_2 is one, whose configuration predisposes them to form networks (Biek,Bayley,1979:2). Those networks are relatively pure and if suitably formed will click into stable, rigid and crystalline position (Biek,Bayley,1979:2). Modifiers (fluxes), such as alkali carbonates or compounds of sodium and potassium, were added to network in order to produce a more flexible structure (Biek,Bayley,1979:2). The most difficult step in opening up the manufacture of the raw material was essentially the pyrotechnological one, the reaction of the flux with the silica bearing mineral (Oppenheim,1970:109).

The main sources of alkalis open to the early Islamic glassmakers were large scale deposits resulting from the evaporation and drying up of former land-locked seas and lakes (soda) and the ashes of plants (Turner b,1956:283;Lucas,1989:179;Nicholson,Henderson,2000:195;Brill, 2001:25;Sawada *et al.*,2003:178;Henderson,2003;Freestone,2006:204;Freestone,2008:84; Degryse *et al.*,2009:53;Henderson,2013:269). The two alkalies were distinguished in the 18th century (Turner b,1956:39). The differences noted in two alkalies were associated not with the specific chemical variations in the content but with the choices of the early Islamic glassmakers and the geographical origin (Turner b,1956:44;Tanimoto,Rehren,2008:2572). Sayre and Smith made numerous analyses of ancient glasses and defined two different compositional categories of Islamic glasses that differ to the concentration of potassium oxide (K_2O) and magnesium oxide

(MgO) (Sayre,Smith,1961:1824-26;Oppenheim,1970:111;Freestone,2006:204;Degryse *et al.*, 2009:53;Wedepohl *et al.*,2011:82;Wood *et al.*,2016). In the first category, mineral soda-lime-glass, both of the two oxides are relatively low (0.1-1.0% and 0.5-2.5% respectively) and in the second category, plant-ash glass, both are higher (1-4% and 3-7% respectively) (Oppenheim,1970:111;Wedepohl *et al.*,2011:82). The high compositions of both the oxides show that they have been made by natron and the low concentrations with the use of marine or inland plant ashes as the source of alkaline (Oppenheim,1970:111). Brill stated that silica is the predominant component of glass with small influences of stabilizer and flux (Brill,1970;Brill *et al.,*1999). By deliberately adding small quantities of colouring, opacifiers and clarifiers the glassmakers understood the material and were able to control the glass melting and the amount of the effective colouring element added (Biek,Bayley,1979:2;Henderson *et al.*,2005:665). Alkalies lower the temperature of pure quartz from 1710° C to a minimum liquids temperature at the ternary eutectic of 725° C (Henderson,1985:272).Glassmakers repeated heating, melting and cooling off the basic materials with those special ingredients adding at a certain point and cooling them quickly in order to create a super-cooled liquid. This super-cool liquid was then fashioned into an enormous variety of shapes and forms (Turner,1956:296;Oppenheim,1970: 36;Henderson *et al.*,2005:665).

From numerous analyses of Egyptian Islamic glass weights Sayre (Sayre,Smith,1961), Matson, (Matson,1949), Gratuze and Barrandon (Gratuze,Barrandon,1990)showed that before AD 845, the glass weights had low magnesium and low potassium values (natron glass) and after this high magnesium and high potassium values (plant-ash glass) (Freestone, 2006:204;Degryse *et al.*, 2009:53;Wedepohl *et al.*,2011:82;Henderson,2013:260;Scott,Degryse,2014:20). This technological change was a reflection of what was happening in Egypt and not necessarily in other parts of the Islamic world. The scientific analyses of glass from al-Raqqa show plant -ash glass manufacture and a phase of earlier experimentation (25 years earlier) there before c.845 when a new alkali source had been documented in Egypt (Henderson *et al.*,2004:458;Henderson e*t al.*,2009:427). Natron was widely used during the 5th century B.C. until the 9th century AD (Sayre,Smith,1961;Henderson,1985;Gratuze,Barrandon,1990;Wedepohl,1997;Scott,Degryse, 2014:20). Natron had already been used from very early times as a detergent in medicine, in cleansing and in a process of embalming the dead and had been exported as a raw material for a long period (Turner a,1970:40; Turner b,1956: 283). The alkali is firmly associated with Egypt (Biek,Bayley,1979:3). Pliny (1st century AD) devotes space to mineral substances, and to their applications (Turnera,1956: 40). The author described various ways in which natron is obtained and said that it was prepared in Nile water in Egypt (Turner b,

1956:284;Freestone,2008:77;Scott,Degryse,2014:15). Two sources of natron mentioned Naucratis in the Nile Delta and Memphis, some two miles south of the present city of Cairo (Turner b,1956:284,Freestone,2008:84). The nitrum from Memphis was of inferior quality (Turner b,1956:284). Agricola (1556) also mentioned the Nile water was led though sluices and by channels into pits or pans where it evaporated and yielded 'salt' (Turner b,1956:284).

Deposits of evaporites (rich in sodium) comprised one or more of the minerals trona, thenardite, burkeite and halite of the period of interest to the glassmakers, and according to the ancient and medieval literature can be found at Wadi Natrûn (west of Cairo) and at al-Barnuj (in the western Delta) and possibly in other locations (outside Egypt at Lake Van in Armenia and Lake Picroli (Freestone,2006:204;Freestone,2008:84;Wedepohl *et al.*,2011:94). Wadi Natrûn, a 45-km-long depression in the Western Desert, half-way between Cairo and Alexandria was the oldest production site. The site contains more than eight various size lakes that are dry during the summer and most retain saline to super saline brines (Wedepohl *et al.*,2011:94). Wenigwieser (Wenigweiser,1992) and Shortland (Shortland,2004) studied the mineral constituents of the evaporites and proved that halite (NaCl) was the dominant mineral, thenardite ($Na_2 SO_4$) was a major component of four of the lakes and trona ($Na_3H(CO_3)2.2H_2O$) occurs at the rims of the evaporite zones (Shortland *et al.*,2011;Wedepohl *et al.*,2011:94). All the above minerals occur mixed in the evaporites deposits but the glassmakers use only trona as a flux in the production of soda-lime glass separating the contaminants halite and thenardite by hand picking (Wedepohl *et al.*,2011:94). The process of handing picking trona with pincers on the flat bottom of the lake at Wadi on a spring day was described at the late 18th century (Wedepohl *et al.*,2011:94).

The scientific analysis of the natron glass widely used until AD 845 show five major compositional groups in the eastern Mediterranean and Near Eastern region (Freestone *et al.*, 2000;Freestone *et al.*,2002:264;Freestone *et al.*,2002:168;Freestone, 2005:008.1.7). Four groups of natron glass were identified by Freestone and colleagues in 2000, to which another one was added two years later (Freestone,2001:111;Freestone *et al.*,2002:168). The mentioned groups are the ***Egypt I***, ***Egypt II***, ***Levantine I***, ***Levantine II*** and the HIMT group (Freestone,2001:111;Freestone *et al.*,2002:265;Freestone *et al.*,2002:168;Freestone, 2005:008.1.7). Each group is restricted in chronological and geographical distribution (Freestone *et al.*,2002:167). But not all the natron type glass fit into these groups as the boundaries of some groupings generally overlap or are not clear (Freestone,2005:008.1.7). ***Egypt I*** group characteristic of the 7th century AD was identified by analyses of Islamic glass weights by Gratuze and Barrandon (Gratuze,Barrandon:1990). The chemistry of the glass shows a low concentration of lime and a high of alumina. The pioneering job of Sayre and Smith (Sayre,Smith,1961) and

later of Nenna and colleagues (Nenna *et al.*,2000) shows an association of ***Egypt I*** with the Natrûn Wadi (Freestone *et al.*,2002:168,Nenna *et al.*,2005;Freestone, 2005:008.1.7).

Egypt II group characteristic of the 8th-9th centuries AD was identified by Foy *et al.* (2003) (Freestone,2001:111;Freestone *et al.*,2002:265;Freestone,2003:111;Freestone,2005). The analysis of the glass shows a relatively high concentration of lime and low concentration of alumina (Freestone,2001:112; Freestone *et al.*,2002:168). The origin of the glass is unspecified, probably Egyptian (Freestone,2001:111,Freestone *et al.*,2002:167). The glass was made using a sand containing limestone probably in inland Egypt and seems to be produced under a fixed recipe for consistent properties (Freestone *et al.*,2000:65;Freestone,2001:112;Freestone, 2003:111). The ***Egyptian II*** glass was better quality than the glass produced in the Levantine coast and its properties, lower viscosity and lower temperature, was ideal for a glassmaker (Freestone,2003). Products of this group can be found at the secondary workshops Fusṭāṭ (Shindo,2000), Tel Aviv (Freestone *et al.*,2015), and El- Ashmunein (Bimson,Freestone,1985), also at the consumer context of Raya (Kato *et al.*,2009) and the monastery of Wadi al-Tur (Kato *et al.*,2009). Freestone and his colleagues using trace element analysis show that the early Islamic glass produced by the Eastern Mediterranean beach sand had with high strontium levels that reflect the presence of fresh shell (Freestone,Gorin-Rosen,Hughes,2000:65). The ***Levantine I*** group characteristic of the Byzantine period (between 4th-7th centuries AD) originates on the Palestinian coast using the renowned sand from the Belus delta in the Bay of Haifa or similar coastal sands (Freestone *et al.*,2002:168). The sand was appropriate because contained the right amounts of quartz and calcite so to they could be mixed with soda (probably from the Wadi-Natrun in Egypt) to produce a blue- green glass (Freestone *et al.*,2003;Freestone *et al.*,2008). The precise location of primary furnaces of ***Levantine I*** group has not been identified (Freestone *et al.*,2002:172).

The ***Levantine I*** glass by early 8th century AD displaced by glass produced on a large-scale at the Bet Eli'ezer furnaces, near Hadera in Israel (Freestone *et al.*,2002:168). The ***Levantine II*** group may be distinguished from the ***Levantine I*** group for its lower lime and sodium and concurrently higher silica concentrations, indicating a different silica source but still some local coastal sand on the Palestinian coast (Freestone,Gorin-Rosen,1999;Freestone *et al.*,2002a,2003). Freestone and his colleagues observed the reduction of the sodium contents to 12.1% that could allow the production of more glass for the same quantity of alkali (Freestone *et al.*,2000:65). The ***Levantine II*** group was produced routinely at primary glassmaking furnaces at Bet Eli'ezer during the 6th and the 7th century AD. Here, seventeen glass furnaces produced about eight tons each of glass with a remarkably consistent composition. Recent discoveries from Ramla extended its

production period until the 8th century AD(Freestone *et al.*,2002). The product of the group was excavated at Bet Eli'ezer (Freestone *et al.*,2000), at Raya (Kato *et al.*,2009), at the monastery of Wadi al-Tur (Kato *et al.*,2009) and at Tel Aviv (Freestone *et al.*,2015).

Outside of northern Israel a fifth glass type with relatively high iron, magnesium, manganese and titanium oxides has been identified by the analysis of raw glass from Carthage by Freestone and of glass from shipwrecks by Foy and colleagues (Foy *et al.*,2000;Freestone *et al.*,2002:168;Foy *et al.*,2003). This ***HIMT*** group is characterized by relatively low concentration of lime (5-6 %) and high sodium (18-20%). The absence of the group from northern Israel and its abundant presence around Mediterranean strongly indicates that it was not produced on the Levantine coast (Freestone *et al.*,2002:172). The products of the group become widespread in the 4th century AD but have nominated by the ***Levantine I*** glass type (Freestone,Greenwood,Gorin-Rosen,2002:172). The two types it is likely to be in competition to supply glassworkers around the Empire, and beyond (Freestone,Greenwood,Gorin-Rosen,2002:173). The distinction between the ***HIMT*** and ***Levantine I*** group is often possibly at the excavations as the ***HIMT*** glass has a yellow green to olive color in contrast with the aqua blue of the ***Levantine I*** glass (Freestone,Greenwood,Gorin-Rosen,2002:172). The elemental analysis demonstrate that the ***HIMT*** glass was widely traded as far as northwestern Europe (Billingsgate Bath House, London), German, Italy, Cyprus, North Sinai and Ramla(Freestone *et al.*,2002:168). The ***HIMT*** group is characteristic of the 4th to the 7th century AD (Freestone,2001:111).

Historical, archaeological, archaeometric and ethnographical studies have shown that the natron glass production was divided between primary and secondary workshops (Henderson,1985:268; Freestone *et al.*,2002:173;Freestone,2005:008.111;Freestone,2006:201;Freestone,2008:79; Degryse,Shortland,2009:136;Reade,2012:321;Henderson,2013:267). The natron glass was fused from raw materials in the primary workshops (Freestone,2008:80). The glassmakers first melted the raw materials and then broke the large slabs of glass into angular lumps (chunks). The chunks were distributed to secondary workshops that could only remelt the other people's chunk (Freestone,2008:80). The glass lumps were shaped by blowing, cutting, drawing, pinching or casting in those glassworking centres (***Figure 2.2.1***,Tal *et al.*,2008:85,Freestone,2008:83). Glass making was a much more complex operation than glass melting. The amount of fuel needed for the kiln was large and the quality of the burning materials was very important in obtaining high enough temperatures to make the kiln work properly (Goldstein,2005:11). The glassworkers that could fabricate the most exquisite glass objects didn't have the specialist knowledge of sophisticated recipes of the glassmakers (Goldstein,2005:11). Only a limited number of artisans



Figure 2.2.1: *Raw glass chunks from a secondary workshop at Ramla (Tal et al. 2008:85).*

who may have been related by clan or family ties had the requisite knowledge of glassmaking. The glassmakers were trying to hide the secrets of their crafts from their competitors. A single glassmaking centre could produce colored or colorless glass with more than one chemical composition (Freestone,2008:79). The different chemical composition from one workshop shows attempts to produce a variety of colors or a variety of ingredients to produce in combination with other raw materials new and better types of glass.

Natron glass production dominated from about 800 BC until about AD 800 in the Mediterranean and northern Europe (Henderson,2016:23). In the 8th and 9th century AD an important radical change in glass technology occurred (Henderson,2016:23). The high-magnesia plant-ash glass gradually substituted for the low-magnesia natron glass across the Islamic world (Sayre,1965;Gratuze,Barrandon,1990;Brill,1995;Henderson,1995,1999,2000;Freestone *et al.*, 2000;Henderson,2013). The radical technological change occurred in a period when the powerful ´Abbāsid caliphate unified broad areas of the Middle East and central Asia (Henderson,2016:23). Muslims, Jews and Cristians glassmakers searched for new local alkali sources and were responsible for fully reintroducing plants (***Salicornia herbacea, Salsola, S.***

fruitcosa, and S.lignosa) that grew near the sea or on desert in glass production (Sanderson,Hunter,1981:263;Lucas,1989:179;Freestone,GorinRosen,1999:116;Nicholson,Henderson,2000:195;Brill,2001:25;Henderson,2002;Sawada *et al.*,2003:178;Colomban,2010:2;Henderson,2016:23). The change took place when the early craft was still in existence (Freestone,Gorin-Rosen,1999:116). There was a period of experimentation in which the glassmakers familiarized themselves with the new ingredients and made a lot of trials with the aim of producing glass with the appropriate technical properties, chemical stability and the right compositional reproducibility for large-scale production (Henderson *et al.*,2004:457).

Large quantities of plant-ash glass start to produce during the 10th and 12th centuries AD at massive tank furnaces in Tyre at the Levantine coast in zones where natron glass has previously been fused (Freestone,2002:50;Henderson,2016:23). The experimentation with new combination of raw materials occurred in an Islamic complex at al-Raqqa (Henderson et al.,2004:458;Wood et al.,2016). The scientific analysis of glass from al-Raqqa show that there occurred one experimental glass type produced in low melting/working temperature (Henderson,McLoughlin,McPhail,2004:458). The cause of that change is still unclear (Sawada *et al.*,2003:178). Whether or not the slow evolution of the glassmaking techniques and knowledge of the raw materials and the increased sophistication of glass design are some of the reasons for that change has remained obscure. Chemical analyses show that natron must have been expensive or difficult to obtain as the content of soda in glass was extremely low (Freestone,Gorin-Rosen,1999:116). The political and economic changes that were taking place may have been related with the change (Freestone,Gorin-Rosen,1999:172). Particularly, the political upheaval within the Delta and northern Egypt from the 7th century AD onwards and the use of natron for other purposes may have been the reasons for that change (Schibille,2011:2; Edwards,Vandenabeele,2012:271).

The chemistry of early Islamic plant-ash glass is more complex than that of the natron glasses (Brill,1999;Henderson *et al.*,2005; Freestone,2006:220;Tite *et al.*, 2006;Barkoudah, Henderson, 2006;Wedepohl,Simon,Kronz,2011:93;Henderson,2016:20). When Turner in 1956 chemical analyses plant glasses was unable to define variations in the composition of plant glasses (Turner,1956;Barkoudah,Henderson,2006,302). Later in 1999, Brill published a range of plant ash compositions (Brill,1999;Barkoudah,Henderson,2006:302,Wedepohl,Simon,Kronz,2011:93). In 2006, Tite and his colleagues, Barkoudah and Henderson demonstrate the large variability of compositions of plant glasses (Tite *et al.*,2006;Barkoudah, Henderson,2006;Wedepohl,Simon,Kronz,2011:93). A number of factors can determine the chemical composition of the plant-ash such as the environment where the plant grew, the specific

pieces used, the manner in which they were burned, the melting conditions and the purification of the ashes (Turner b,1965:291;Brill,1999;Henderson,2002;Barkoudah, Henderson,2006:297; Colomban,2010). The compositional characteristics of the plants were dependent on the geological zone in which the plants grew (Barkoudah,Henderson,2006:297). The chemical analysis and historical descriptions show that halophytic and alkali plants, which grew in semi-desert and evaporite environments in the Middle East and elsewhere and belong to the Chenopodiaceae family, have been used in glass production more than 3000 years (Barkoudah, Henderson,2006:299;Schibille,2011:2). These plants concentrate alkali salts as sodium in their tissues by photosynthesis so sodium predominates over potassium as the most abundant constituent (Barkoudah,Henderson,2006:297;Wedepohl *et al.*,2011:93). The proportion of the alkali in the plant-ash that interacts with the silica was the most important for the glassmakers (Barkoudah,Henderson,2006:297).

Halophytic plants, including *Anabasis*, *Arthrocnemum*, *Halopeplis*, *Hammada* (*Haloxylon*), *Salicornia*,and *Salsola* were widely used (Barkoudah,Henderson,2006:297).The earliest plant used in glassmaking must have been *Salicornia* (Turner b,1956: 285; Brill,1970:110; Henderson, 1985:274). *Salicornia herbacea* is a salt marsh plant that occurs in maritime and inland saline areas associated with coastlines, tidal flood ways, and slat lakes (Rhee *et al.*,2009:548; Milic,2013:1260). *Salicornia* the specie of *Chenopodiaceae* and other salt-tolerant halophytes plants, such as *Haloxylon articulatum* (*Hammada scoparia*), *Anabasis syriaca* and species of the *Salsoda* families (including the plant known in the Middle East as *keli*) which dot the desert or line marshy regions in Iran, Iraq, Syria, and elsewhere within the area of our interest were harvested, gathered and burned to obtain hard chunks of strongly alkaline ashes for glassmaking (Turner b,1965:285;Brill,1970:110;Biek,Bayle,1979:6;Henderson,1985: 274;Jackson *et al.*, 1998:17;Henderson,2002;Baker,2004:12;Henderson,2005:667;Freestone,2006:7;Barkoudah, Henderson,2006:300).

The literature sources refer to the sources of the plant ashes used in glass production, to the great quality and to the profitable exporting of those plants. The mixture of glass with *kali* (plant ash) by heating them for a few days is described in Almass'oudi book (AD 957) and in Elbayrouni's historical book (AD 990)(Barkoudah,Henderson,2006:299). The document from the Cairo genizah in AD 1011 describes the primary glass produced at Tyre using local plants and later James of Vitry refer to the great quality of the plant ashes of the site (Henderson,2013:268). At the end of the 10th century AD Al-Muqaddasi mentioned the profitable exporting of ushan plant ash from Aleppo (Henderson,2005:667;Barkoudah,Henderson,2006:300). The geological location plays a significant in the chemical composition of the plant ashes. For example, plants

that used to grow in an environment in which metals were smelted can contribute to the minor and trace elements in coloured, colorless and faint tinted Islamic glasses (Barkoudah, Henderson,2006:318). Barkoudah and Henderson's analyses show clear that some heavy metals, such as lead, zinc and tin accumulate in halophytes plants (Barkoudah,Henderson,2006:312). It is certainly anticipated that the ash from any particular plant has a different composition according to the locality in which it is grown but since a plant must draw all its mineral content from the soil, if the soil later becomes impoverished or changes its compositions, then the composition of the plant that grows in that location will also change (Turner b,1965:291).

The medieval glassmakers deliberately used a small quantity of colouring, clarifying and opacifying, elements into the glass melting. Antimony and tin were the main opacifiers and have been studied by Turner and Rooksby (Turner b,1970;Henderson,1985:282). Chemical analyses show that the glassmakers intentionally introduced antimony into the glass batch from a mineral like stibnite (Henderson,1985:285). The stabilizer was lime (CaO). The presence of lime in glass came with the sand of marine shells or in the plant ash and was essential for stability (Biek, Bayley,1979: 5;Goldstein,2005:11;Henderson *et al.*,2005:665). Lime is the next more abundant component after silica and soda (Freestone,2005: 008.1.6). The component it is generally present in a range of 5-10% (Freestone,2005:008.1.6). Glasses which didn't contain sufficient lime were unstable over the time (Freestone,2006:213).

Nowadays the strontium analysis shows that the isotopic composition of the sea water is inherited by the $CaCO_3$ in the form of invertebrate shells and limestone (Freestone,2005:008,1.6). The high concentration of Sr in the natron glasses suggests that the lime was added to the glass in the form of marine shell (aragonite) and the low concentration indicate that the lime added in the form of limestone (calcite) (Freestone,2005:008,1.6). Early Islamic natron glass with lime added from particles of shells of the Eastern Mediterranean coast uncovered from the tank furnaces at Bet Eli'ezer (Freestone *et al.*,2000:71). In contrast glass from an inland workshop in the Middle Egypt, Tell- Ashmunein has low concentration of lime that indicate the lime was added in the form of limestone (Freestone,2005:008,1.6). The concentration of Sr in the plant ash glasses inherited from the plant material is quite high. Plant ash glass with high content of Sr was uncovered at Banias, Israel (Freestone,2005:008,1.6).

A wide variety of metallic oxides, pigments and colouring ions were used during the later stage of the melting process (before the final melt or after the basic glass is fully formed) for aesthetic reasons in order to colour the colourless or the weakly-coloured glass (Turner b,1956:296; Biek, Bayley,1979:2;Henderson,1985:278;Hasson,1979:3;Goldstein,2005:11;Colomban,2012:245).

The metallic oxides that were often used were copper, cobalt, iron and manganese (Turner a,

1956;Biek,Bayley,1979: 7;Henderson,1985: 280;Freestone,2006:17). Copper, as a colorant, was used to produce a light blue or turquoise or ruby colour and under reducing conditions to produce opaque red colour (sealing-wax red); leaded bronze to produce a turquoise green colour; cobalt, as a colorant, to produce a dark blue; manganese, as a colorant, to produce purple, violet or wine colour and lead to produce colourless glass (Turner,1956:48;Henderson,1985: 281;Shortland,2003:3;Colomban,2012:273;Henderson,201:264). Gold was used as a colouring agent to produce a ruby red colour (Turner a,1956: 50;Henderson,2013:76). Lead in the Islamic period was not essential to produce the white opaque colour but possibly was used in glassmaking in order to make lead oxide-silica glass and to add brilliance to a colourless glass (Henderson,2013:264). Iron as an impurity gave rise to the green colour and was often used as a specific added constituent to produce certain types of glasses (Turner a,1965:48;Henderson, 2013:67). The use of iron in purple and flesh-coloured glasses can give a yellow colour (Henderson,2013:67).

The colorant cobalt used in Sāmarrā during the early Islamic period was characterized by zinc and iron (Henderson,2013:73). As a colouring agent, cobalt was used less frequent than copper (Henderson,2013:70). The form of the colorants varies. It could be a mineral ore, frit, cullet or cakes of highly coloured glass (Henderson,1985:278). The sources of cobalt were relatively few and they were identified by their traces elements (Robertshaw *et al.*,2010:1908). One or more known sources of cobalt tin is the ores found at Iran, one of each is erythrite (Robertshaw *et al.*, 2010:1908). Abul' Qasim (AD 1302) refer the cobalt minerals including rich Mn exploited at the Qamsar (Robertshaw *et al.*,2010:1908). Another one is arsenical cobalt source found at Qamsar and a zincian cobalt ore found at Anorak near Tabriz (Freestone,Stalpeton,1998:123; Henderson,1998:118). From Qamsar sources was exploited the cobalt pigment found in the 9th century AD blue glazes on Sāmarrā faiences (Robertshaw *et al.*,2010:1908). Cobalt tin sources can be found also in south Asia and in Rajastan, India (Robertshaw *et al.*,2010:1908). Cobalt mineral could be either refined by being crushed, washed and roasted or unrefined containing proportions of the colorant element (Henderson,1985:278). The colorant could also be a frit containing the colorant oxide diluted (Henderson,1985:278). A glass batch without any metallic oxide had a natural amber to green colour owing to the presence of contaminants from the sand (Hasson,1979:3;Colomban,2012:275). The main contaminant was iron. Even the cleanest sand usually contained enough iron to confer a faint greenish tinge (Biek,Bayley,1979:6, Colomban,2012:275). The removal of impurities or undesired constituents must always have been difficult and could be accompanied by a succession of scientific operations. The glassmakers must have been searched out raw materials that contained less iron (Brill,1995:212).

Decolourizing components went into solution under oxidizing conditions to neutralise the iron colorant effect (Henderson,1985:281;Colomban,2012:275).

Aqua color glass was special and related with the raw materials. Soon the glassmakers in their efforts to produce water-white glass must have realized that connection (Brill,1995:212). The composition of colorless glass differs significant from the other glasses in the lower concentration of soda and alumina and higher in magnesia and silica (Brill,1995:212). The colorless glass has also lower concentration of titanium, barium, strontium and zinc (Brill,1995:212). The lustrous mineral stibnite and manganese could bleach glass to a very pale yellow colour and were widely used(Biek,Bayley,1979:6;Henderson,1985:284;Shortland,2003:2;Henderson,2013:77).

Antimony was known quite early in medicine, glassmaking and metalworking (Oppenheim, 1970:21). Antimony could normally produce a more brilliant colourless glass than manganese (Henderson,1985:284). Antimony was replaced by tin for yellow glass and tin oxide for white glass (Colomban,2012:274). Manganese could produce a colourless glass (Biek,Bayley,1979: 6; Brill,1995: 212). The mineral pyrolusite that bears manganese was used as an oxidant in Islamic glassmaking (Freestone,2006:17). The element commonly found as an impurity at a level about 0.05% (Brill,1995:123). When the manganese levels reaches or excessed 0.15% then we tend to think that was deliberately added although it is difficult to draw a sharp dividing between the background impurities and the intentional additive (Brill,1995:123). During the Islamic period very often the manganese (MnO) found in excess of about 0.3% (Brill,1995:123). Manganese as decolorant was not always successful because of the reducing furnace atmosphere or because its concentration was too low or because introducing into the batch had been in a chemically reduced state (Brill,1995: 213). Lead oxide was another compound used by Muslims during the 9th century AD in the manufacture of translucent glass (Henderson,2013:267).

Historically speaking, there were several practical aspects of combine in all the above raw materials during the early Islamic period (Henderson,2013:257). Whichever of the two typical sources of alkalies, natron or plant glass, were used for the production, the glassmakers would be faced with the fact that part of the material could not be incorporated into the glass. Only the carbonates, bicarbonates, sulphites and sulphides are readily reactive with sand, the sulphates are slowly reactive, while the chlorides are particularly so stable and non-reactive that they melt without decomposition (Turner b,1956:291). There were different methods that the glassmakers were using in order to start the decomposition of sodium sulphate to sulphites or sulphides. One way demanded the use of carbonaceous or reducing agents at a temperature of 600° C (Turner b,1956:291). Turner noted that the solid compounds (sand and sodium carbonate) remain in a powdered state below 700° C (Henderson,1985:270). Gases could produce gas bubbles that

mean glass of lower quality. Gases could be driven out of the melt in higher temperatures (Henderson,2013:274). Another way was without the presence of reducing material at a temperature at least 1200° C (Turner b,1956:291). The first way that was carried out in two stages at low temperature seems to be discernible during the Roman period but not so popular during the early Islamic period where the second is the most evident (Freestone,2008:79).

The large scale of early Islamic production brought into existence large tank furnaces (Freestone *et al.*,2003:22). There were several types of furnaces. The tank furnaces and their associated structures will be discussed in the next section. The products of those primary furnaces, whichever type of furnace was used (large tank furnaces or two-three furnaces) were chunks of colourless or naturally coloured glass and cullets (scrap glass) (Freestone,2002,65;Freestone, 2006:202). The well-documented archaeological evidence nowadays shows that the products of the glassmaking workshops were widely traded in a great geographical area during the 'Abbasīd period (Goldstein,2005:11;Freestone,2006:201). The 11th century AD Serçe Limani shipwreck at the Turkish coast brought evidence that raw glass, collected from glassmaking workshops, was also traded during the Islamic period (Secre Limani, Henderson,2013:270). The glass cargo of the ship was almost two metric tons of raw blocks up to 30 centimetres (Henderson,2013:270). The 11,000 lid moils, rough-rimmed glass discs from the manufacture of bowls and beakers show that raw glass was collected not only from glassmaking but also from glassworking workshops (Henderson,2013:270). The cargo was stowed in baskets. A Hebrew document from Ezra Synagogue in Fusṭāṭ refers to baskets (mašpalôt or mišpalôt) of glass in a shipment (Carboni *et al.*, 2003:144). The document, written on January 31 (1011), speaks of glass (zekûkît). Zekûkît would probably be raw glass but it is still uncertain (Carboni *et al.*,2003:144). There were 37 baskets (which may have weighed as much as eight tons) (Carboni *et al.*,2003:144). Merchants or glassworkers probably from Tyre sent glass to Fusṭāṭ (Carboni *et al.*,2003:144). Tyre under the Crusaders (AD 1154-1227) produced high quality glass which was famous internationally (Carboni *et al.*,2003:144). Tyranian glass was used in the manufacture of remarkably translucent glassware and was probably exported as a raw material (Carboni *et al.*,2003:144).The neighbouring Acre also produced raw glass of great purity. Archaeological excavations also recovered chunks of raw glass at al-Raqqa, at Acre and at Tell as Sumeiria (Carboni *et al.*, 2003:144). Evidence of glass workshops that specialized in producing large glass slabs has been found mostly on the Eastern Mediterranean coast (Carboni,2006:297).The large slabs of glass were shipped far from the Eastern Mediterranean coast along the Black Seas or possibly in Southern Europe to glassmaking areas where the raw material was not readily available (Carboni, 2006:297). The destination of those products was glassblowing workshops.

The glassblowing workshops collected raw glass to remelt them at furnaces where considerably lower temperatures were demanded (Goldstein,2005:11). That process was less expensive and demanded simpler technology (Carboni,2006:297). The location of the construction of those furnaces was carefully chosen; sometimes a rather elevated, sparsely inhabited area that was somewhat removed from the major administrative center it served (Tal,Jackson-Tal,Freestone, 2008:95). The archaeological excavations at al-Raqqa, Sīrāf and Ramla show the primary glass furnaces have been found along with glassmaking or pottery kilns (Whitehouse,1868;Tal, Jackson-Tal,Freestone,2008:95;Henderson,1995). This indicates that the two industries coexisted in some areas. It is furthermore possible that glassworker worked in cooperation with potters who likewise used kilns. Since the exercises of both crafts required the essential technical know-how to work the furnaces, the glassworkers and the potters could work together under especially favorable circumstances producing ceramic and glass.

Luxury glasswares were produced by glassmakers using mold-blowing, stamped and applied ornament and wheel-cutting techniques before the ‘΄Abbāsid caliphates (Pinder-Wilson, 1968:98). The previous Sasanian glassworking industries provided the prototypes for Arab glassworkers and facilitate a degree of continuity into the Islamic period. The most striking and finest products were cut-glass items with linear or facet cut in quincunx or honeycomb design (Charleston,1942:213;Harden *et al.*,1968:98;Pinder-Wilson,1968:98;Klein *et al.*,2000:58). Characteristic of the cut glass were the hemispherical bowls in colourless and thick glass decorated with concave facets (Harden *et al.*, 1968:98;Pinder-Wilson,1968:98;Klein,Lloyd, 2000:58). Small hemispherical bowls were exported to the East and West, some even reaching Japan in the 6th and 8th centuries AD (Harden *et al.*,1968:98;Pinder-Wilson,1968:98;Klein *et al.*,2000:58). Medieval Arabic literature mainly the work of geographers, philosophers, poets and commentators, does not contain much specialist information about the manufacture of Islamic glass because writers were more interested in other matters (Baker,2004:12). Our awareness of glass production in the lands of the early Islamic world has grown with published information regarding the glass finds emerging from the controlled archaeological excavations (Baker,2003: 167).

Early Islamic glass production from Egypt in the west to central Asia in the east produced a wide variety of glass, commonly known in Arabic as zujāj and in Persian as ābgīneh, which could be either luxury or glass for everyday use (Baker,2004:7,The Metropolitan Museum of Art Bulletin). The glass colorless glass was especially admired and appreciated (Baker,2003:167). Luxury glass played a significant role in early Islamic society and was appreciated as far as China and Japan (Baker,2004:7). This type of glass, as a prized item of exchange or diplomatic gifts from the

caliph has been found not only within its area of production but eastward to China and Southeast Asia and westward to Europe and North Africa (The Metropolitan Museum of Art: 28). Al-Ma'mun (r. 813-17), cited in al-Qaddūmī (al-Qaddūmī,1996) and in Baker (Baker,2004:7), sent to an Indian ruler, among other luxury gifts, a very thick glass goblet of Egyptian glass which was engraved in high relief and had a presentation of a lion faced by a kneeling man. Enamelled vessels of high value also were given as gifts or commissioned by Ayyūbid rulers Jarizan atabags and Anatolian Seljuq sultans (Henderson,2013: 258). According to al-Jahid (d.c 868 CE) (al-Jahid,1997:39), cited in Baker (Baker,2003:167), glass vessels sometimes in the eastern provinces of the ´Abbāsid Empire were preferred even over gold vessels because they were transparent, non-porous and non-absorbent.

Syrian glass was acknowledged as the finest in the medieval period (Lukens,1965:198;Baker, 2004:12;Goldstein,2005:11). Syria was probably the place where the Roman techniques and traditions became known to the Islamic glassmakers (Lukens,1965:198). In AD 1038 Tha'alibi (1956) cited in Bosworth (1968) noted that Syrian glass was proverbially famous for its thinness and translucence and its major glassmaking workshops located in Tyre, Akka, Hebron, Tripoli, Armanaz, Antioch and Aleppo (Baker,2004:12). The poet Âzād Bilgrāmī, cited in Schimmel (Schimmel,1992:278) and in Baker (Baker,2004:12), recognized the differences between the glass, especially enamelled, of the various centres in Syria as he alluded to the vaults of the heavens and queried "*in dealing with this old sky, does it matter / Whether it is of European, Aleppan or Syrian glass?*" According to Al-Qazvini, cited in Lamm (Lamm,1941:63) and in Baker (Baker, 2004:12), Aleppo was famous for the wonderful and the best quality of glass. Egypt with a history of glassworking dating back to the Early New Kingdom (1555-1090 BC) shared a distinct decline in glass quality and quantity and the glass industry resurged more than a century after the advent of Islam (Lukens,1965:198). Mesopotamia and Persia already from the late Sasanian times and throughout the first centuries of Islam continued to produce high quality glass (Negro Ponzi,2005:144;Lukens,1965:198;Goldstein,2005:11). The excavations in Mesopotamia have brought to light glass that suggests that a thriving glass industry must have been existed there (Lukens,1965:198). The excavations from Nishapur and elsewhere in Iran also imply the existence of an industry in Persia analogous to that of Iraq (Lukens,1965:198).

Most Islamic glass vessels, such as goblets and beakers, bottles and flasks, tableware, personal ornaments, mosque lamps, perfume bottles, inkwells, gaming pieces and coin weights, as in the Roman world were massed produced for daily use in order to satisfy the needs of the middle class in Islamic society (Hasson,1979:4;Tait,1991:112). The early Islamic glassworkshops also produced a wide range of shapes, dimensions and colors of containers for commercial goods

(Carboni,2006:297;The Metropolitan Museum of Art: 28). Countless shades of green, blue, yellow, purple, brown and colorless glass were used for all manner of liquids and powders, perfumes, oil, wine, chemicals, pharmaceuticals, cosmetics, rosewater, spices, pigment filled bottles, jars, flasks and vases (Carboni,2006:297;The Metropolitan Museum of Art:28). The vessels served medical purposes including 'test-tubes', vessels for bloodletting and cupping glasses (Hasson,1979:4). The early Islamic glass workshops also produced economically viable glass for everyday use. The glass was produced for architectural and decorative purposes to make windows and probably tiles for a wall or floor panel (Baker,2003:167;Baker,2004:6;Carboni,2006:297; Henderson,2013:257). Numerous window shards in various colours have been found in different parts of the Islamic world. In the mid-9th century small lozenge and circular pieces of glass found at the ´Abbāsid royal complex of Jawsaq al-Khāqānī in Samārrā seem to be used to form a wall or floor panel (Baker,2004:6;Henderson,2013:257). Millefiori glass tiles for floor or wall panels were also found in the same palace (Baker,2004:6). Window glass and glass tiles probably for the floor were also found in the complex Qasr al-Hayr that was built around AD 728-9 (Baker, 2004:6). The tiles were transparent colourless glass with a slight green or a turquoise tinge and had parallels with similar polished translucent aqua green blocks glass that were found at the 'audience hall' of the ´Abbāsid caliph, al-Mu'tasim in the Raqqa excavations (Lamm,1928:109, 304;Baker,2004:6;Henderson 2013:257).

2.3 Evidence for primary glassworkshops in the Islamic world during the ´Abbāsid dynasty

From the Arabs conquest and onward, volume of glass production increased markedly (Lamm,1930:496-8;Lamm,1935:8;Charleston,1942:217;Saldern,1966:17;Lukeins,1965:198; Hasson,1979:3;Klein *et al.*, 2000:58;Henderson *et al.*,2005:131, Brill, 2009:460. The size of the populations in the urban centres increased, in addition to the presence of a substantial number of troops and that probably led to a massive demand for pottery and glass (Henderson *et al.*, 2005:142).The large demand resulted in primary workshops in the Middle East to melt tons of batches of raw materials in tank furnaces in a single firing (Brill,1967;Gorin-Rosen,1995;Gorin-Rosen,2000;Freestone,Gorin-Rosen,1999;Aldsworth *et al.*,2002;Freestone *et al.*,2003:22; Freestone,2008:79;Henderson,2013:273;Brill, 2009:461). The changeover from melting pounds to melting tons of batches meant that the workshops were concentrated largely in a centralized urban context, in surroundings which provided a natural source of quartz, sand and raw materials (Henderson *et al.*,2005:143; Degryse *et al.*,2009:21;Henderson,2013:266). But where exactly was that place in the Islamic lands (***Figure 2.3.1***)? One of the main objectives of Chapter 2.3 is to present all the evidence, mainly found in the archaeological excavations and the chemical analysis, about the location of the primary glassworkshops in the Islamic lands. The archaeological and chemical analysis evidence shows that before AD 845 natron glass was mainly being melted in tank furnaces in Syria, Egypt and the Levantine coast using local sand and imported natron and after that it changed to plant ash glass (Henderson,1995:434;Henderson,2013:271). The remains of the ateliers which have been found in those areas, with a short description of their associated structures, will be presented here. Workshops that well preserved will be presented in more detail.

The history of glassmaking was incompletely known until the 1930s. The archaeological excavations in the Middle East, especially work undertaken after that period, have increased our awareness (Baker,2003:167). The Eastern Mediterranean coast provides us with an unparalleled richness of archaeological evidence. The coastline at the base of the Carmel Mountains was a place where a number of glassmaking workshops were found (Brill,Woskinski,1965:1-11;Gorin-Rosen,1995:42-43;Vitto,1996:136-141;Rilkin,1998:55-58;Freestone,Gorin-Rosen,1999:105-116;Gorin-Rosen,2000:49-63;Sode,Kock,2001:156;Tal *et al.*,2004:51-66,Freestone,Gorin-Rosen, 2008: 67-78). The mouth of the Belus (Na'aman) River, scarcely 40 kilometres south of

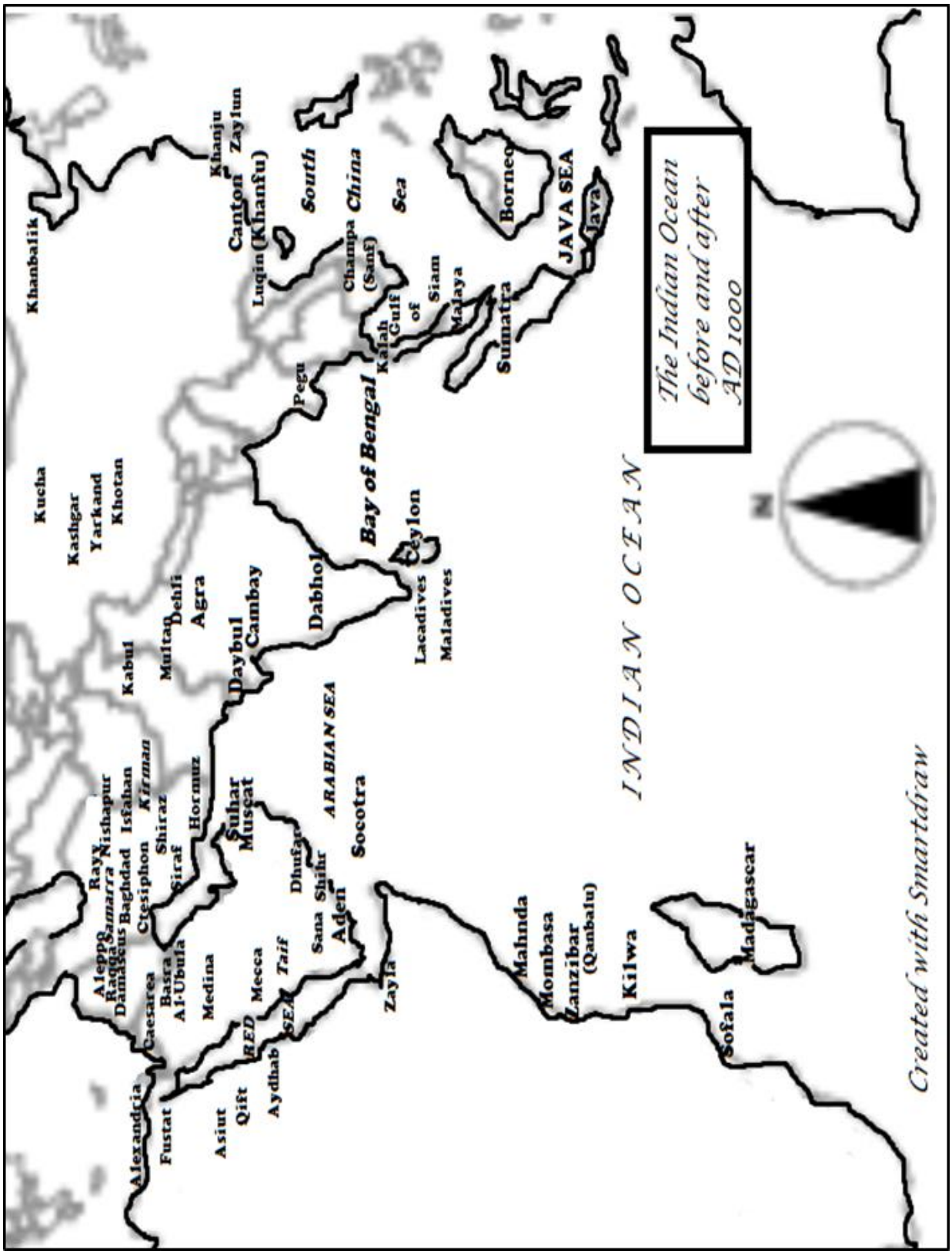


Figure.2.3.1: The Indian Ocean before and after AD 1000.

Tyre, had been vital to glass production for many centuries (Turner b,1965:279; Freestone,2006: 210;Freestone,2008:77;Scott,Degryse,2014:15). The maritime Galilee and the beaches of the Levantine coast were also a suitable place for the development of primary glass production centres (Stern,2006:377;Freestone,2006:201;Degryse *et al.*,2009:20). Primary production has also been demonstrated in al-Raqqa, Syria and in Egypt. There can be little doubt that workshops flourished near those regions. It must be realised that the archaeological information available at present has been gathered from a small number of workshops and it cannot be said with certainty that the production did not take place in different places in the Islamic lands (Rehren,2014:218). The production must have taken place at other places, as in Persia and southern Mesopotamia, but no definite glassmaking remains have been identified (Lamm,1935:8;Freestone *et al.*,2003: 19). The identification of more sites is a matter of chance.

The process of glassmaking must have been active at certain types of sites, near the river or the coast. The location and the history of specific sites in Persia and southern Mesopotamia allow us to suggest the existence of glassmaking workshops. The size of the sites, the large number of people with industrial and commercial concerns who lived there, the glass finds and the volume of goods transported at their harbours render quite unbelievable the hypothesis that no glass workshops were active in those cities. Through chemical analyses Carboni suggested that glass was produced in the area of royal Samārrā in Iraq (Carboni *et al*,2003:147). A survey of the site by Northedge and Faulkner (1987) revealed a centre for glass production close to Sāmarrā palaces and on the north bank of the river Tigris in an area known locally as m'mal al-Zujāj (Zujāj is an Arabic word for glass). The recent archaeological excavations at southern Lebanon proved that Tyre was a major glassmaking centre, at least between the 10th and 13th centuries AD (Carboni *et al*,2003:147). However, Tyre as a glassmaking centre has received less attention in the written sources (Carboni *et al.*,2003:139).

Carl Johan Lamm (1930), who studied the medieval glass, noted only five references to primary production at Tyre in Arabic. The book 'Idrisi's Geography' (1154) refers to the fabrication of an excellent quality glass and ceramic at Tyre (Carboni *et al.*,2003:140). The document that has the power of attorney mentioned a Jewish trader from Tyre that was probably a glassmaker. Benjamin of Tuleda (about AD 1167) cited in Carboni (2003) mentions that Jews at Tyre produced the so-called ''glass of Tyre'', which was prized in all countries (Carboni *et al.*,2003: 146). Benjamin also describes ten Jewish glassmakers encountered in Antioch. Egypt and Fustāt are presented as extensive and long-established glassmaking centres (Carboni *et al.*,2003:141). The 11th century AD Hebrew document concludes with many references to glassmaking especially in Egypt and Fusṭāṭ (Carboni *et al.*,2003:141). The historical sources without the

archaeological evidence need to be carefully examined to prove whether are referring to a primary atelier or to a secondary (Henderson,2003:266). Complications arise in the literary sources because the art historians suggested putative production centres in the early Islamic period (7th-14th centuries AD) the glass vessels production centres (Henderson,1995:433). The sources refer to Raqqa, Aleppo, Damascus and Cairo as workshops that produced highly decorated vessels in a wide range of shapes but a confirmed glassmaking site except al-Raqqa in Syria has still not been excavated. Complications arise in the identification of the evidence for primary glass production centres not only in the literary sources but also in the archaeological excavations.

2.3.1 Complications in the identification of the evidence for primary glass production centres

Before presenting the archaeological evidence for glassmaking it will be helpful to discuss or explain some of those complications that arise in the identification of those evidence. The characteristic types of archaeological evidence can be traces of furnaces, ancillary structures (annealing furnaces), raw glass adhering on the floor or the wall of a furnace, chunks, lumps, and wasters (objects with manufacturing defects). During the identification of glassmaking processes, several risks are run and many difficulties encountered. Glassmaking processes can be easily confused with glassworking or even with metallurgy (Rehren,2014:218). It must be kept in mind that glassmaking is a chemical process with little if any slag or waste left behind, while metal smelting in contrast generates large amounts of durable slag making it more archaeologically visible (Rehren,2014:218).The strongest evidence, perhaps, is the furnace, but in addition, with the presence or absence of certain other elements in the context. The morphology of a furnace does not necessarily distinguish primary and secondary production because much of the secondary glass was melted in tanks rather than in crucibles (Freestone,Jackson-Tal,Tal,2008: 80). Large tank furnaces, together with glazed bricks and large quantities of raw-glass chunks in an absence of moils, drops and blowing wasters indicate the existence of primary industry (Bet Eli'ezer Hadera). The presence of chunks and lumps by themselves are not evidence for glassmaking as they can be found both at primaries and secondary workshops (Freestone *et al.*, 2003:19). Only in Ḥorbat Biẓ'a, Israel, the primary production was established by the large quantity of raw chunks with the glazed bricks probably from the wall of the furnace (Gorin-Rosen, 2012:61). Glass working or manufacturing, in contrast with glassmaking, leaves slightly more archaeologically visible waste (Rehren,2014:218). The moils were left over from the blowing

process of vessels, edges of metal pontils with remains of glass, blowpipe crack-offs, drops, deformed pieces and small discs or "buttons" of glass applied indicate that glassworking activity takes place (Gorin-Rosen,2012:49). The absence of the above glassworking debris (moils and distorted vessel fragments) from contexts containing furnaces suggests the use of the furnace for making raw glass (Freestone,Jackson-Tal,Tal,2008:71). The floor of a furnace containing superposed layers of dirty glass and debris indicates also the existence of secondary and not primary furnaces (Gorin-Rosen,2000: 52;Gorin-Rosen,2012:49).

The extent of the heating is not a clear indicator of primary or secondary process when the temperature is below 900° C. The primary production demands high temperatures, above 900° C. But still primary furnaces could operate at relatively lower temperatures when the glassmaker follows the tradition of the two or three stages of melting the glass. Then the furnace can be easily confused with a pottery kiln, especially on occasions where the glassmaker worked in the same industrial area with a potter who used pottery kilns (Henderson,1999:244). The glassmaking furnace was constructed in a specific way to improve insulation and to absorb heat gradually (Jackson *et al.*,1998:13). A complicated pattern of vitrified mudbrick together with glazed bricks and large quantities of chunks indicate the exercise of the glassmaking craft (Jackson *et al.*,1998:13). The presence of glass wasters, products that have gone wrong or are distorted or discoloured by heat, is important evidence for glassmaking. But even today large wasters are rare (Rehren,2014:218). The wasters were chunks of insufficient size or weight for trade that would have been removed from the slab and were discarded in the working area (Tal *et al.*,2004:57). Large waster glass slabs with failed composition, anomalously high lime were only uncovered in two places in Israel (Brill,Woskinski,1965;Freestone,Gorin-Rosen,1999).The location of a site is indirect evidence. The remains of a workshop a long distance of the coast or the river suggest that the given site probably served as a secondary workshop for manufactured finished products (blown vessels). The long distance of the furnace of the fuel is not actually a problem because the fuel (wood) could be transported. The building of a furnace near the fuel and far away from the coast or a river indicates probably secondary glass production.

Many salvage excavations and surveys were carried out in Israel from the 50s until the present day and brought the most evidence for glassmaking production (Gorin-Rosen,2000:49). The Sharon plain was a place where abundant remains of furnaces, raw glass and glass debris were uncovered. Three sites at the Sharon plain produced raw glass chunks with similar composition. The sites differ in date and geography. South of the Sharon plain was an urban settlement Apollonia-Arsuf. The coastal settlement became an urban centre as early as the Persian period until the 13th century C.E., which suggests that it was a major centre both of primary and

secondary production (Tal *et al.*,2004:59;Freestone *et al.*,2008:67). Central to the Sharon plain was Bet Eli'ezer, Hadera. The site, located between the foothills of Samaria and the coast, was a large glass production centre that produced hundreds of tons of excellent quality glass (Gorin-Rosen,2000:52;Tal *et al.*,2004:59).

2.3.2 Glassmaking workshops during the 6th-7th centuries AD

Apollonia-Arsuf appears to be the earliest glassmaking complex of the early Arab times. Apollonia is part of a coastal plain on a kurkar (fossilized dune sandstone) ridge on the Mediterranean coast of Israel (***Figure, 2.3.2.1***, http://archaeology.tau.ac.il/?page_id=4668, Galor *et al.*,2009:5). The city was an urban centre, noted in several sources that succumbed to the Arabs around 640 C.E. (Tal *et al.*,2004:51;Galor *et al.*,2009:5). The site was excavated in 1950 by Dr. I. Ben-Dor and Dr. P. Kahane of the Department of Antiquities (Perkins,1951:86;Tal *et al.*,2004: 51;Freestone *et al.*,2008:77;Galor *et al.*,2009:5). The excavation reveals remains of what is considered a factory for the manufacture of glass. Two types of glass furnaces and an enormous amount of raw glass were discovered among the architectural remains of a series of wine and oil-presses and other installations of unclear function (Galor *et al.*,2009:5).The area lying northeast of the city wall in the Crusader period where the furnace was found is assumed to be an industrial suburb of the ancient town as no remains of houses were unearthed there (Perkins,1951:86).We may assume that due to the pollution produced by the glassmaking process the furnaces were constructed outside the inhabited part of the urban centre (Perkins,1951:86;Tal *et al.*,2004:86).
The base of a square furnace was uncovered in 1950 in the courtyard of a rectangular building (Tal *et al.*,2004:55).The furnace measured 5.5 m x 5.5m made of tiles and blocks of large stones (Tal *et al.*,2004:55). The construction deserves special attention because it was the first primary furnace discovered in Israel. The furnace consisted of two parts: the furnace itself (the firing area) and the glass floor (the melting chamber, with walls on three sides) (Tal *et al.*,2004:55).
However, the results of a later work show that it had been erected later and served probably as a storage facility (Tal *et al.*,2004:56). Further east in a different area a second square furnace was found (Tal *et al.*,2004:55). Though less well preserved, the furnace consisted of a square floor (Tal *et al.*,2004:55). The pattern of construction on the east-west axis with the firing area on the west and the melting chamber on the east was the same in both of the two furnaces



Figure 2.3.2.1:*Glass furnace at Area N in Apollonia-Arsuf.*
(http://archaeology.tau.ac.il/?page_id=4668)

(Tal *et al.*,2004:58). Why did the furnaces have the firing area facing west? The glassmaker tried to use the sea winds probably to avoid the use of bellows (Tal *et al.*,2004:58).

The large amount of scattered glass across the area suggests that the product of the factory was high quality, with occasional bubbles of raw glass (Tal *et al.*,2004:56). Only two colours were obtained: transparent blue and greenish blue (Tal *et al.*,2004:56). The products of the furnaces were analysed. The chemical analyses show that it was similar to the local glass produced in Israel in 1950 (Tal *et al.*,2004:55). The glass vessels uncovered at the excavations had the same colour. The similarity indicates that the vessels were made by the raw product of the furnaces but since no remains of secondary furnaces had been found the place of their manufacture still remains unknown (Tal *et al.*,2004:79). Roll and Ayalon mentioned that the Sharon plain has a dozen sites related to the secondary production but if the vessels come from those workshops it is still impossible to say (Tal *et al.*,2004:59). The raw materials were sand, sodium and lime according to Kahane (Tal *et al.*,2004:59). The coastal beach was appropriate as it contains the right concentration of quartz and calcite. The short distance from the furnaces to the coast suggests

that they were located near to the source of sand and not near the fuel (Tal *et al.*,2004:59). This supposition must be true, as the coastal-plain sites of the Sharon plain are situated on fossilized dune sandstone where forest to provide wood or branches as the fuel is difficult to obtain(Tal *et al.*,2004:58). The fuel of the furnaces was wood, as the chemical analyses prove, or branches (Tal *et al.*,2004:58). Trees at Apollonia could only be found to the east borders at a long narrow plain (Tal *et al.*,2004:58). The furnaces dated to the 6th or the late early Islamic period (Tal *et al.*, 2004:65). If this supposition about dating is true then the furnaces were probably the work of private entrepreneurs (Tal *et al.*,2004:66).

South of the medieval city wall, evidence of glassmaking production was found more recently (Tal *et al.*,2004:56). The trial excavation in 2002 brought to light lumps of melted glass at four squares but no architectural remains of a furnace (Tal *et al.*,2004:56;Galor *et al.*,2009:11). The furnace remains were found south of the squares (Tal *et al.*,2004:56). The furnace was isolated with the firing area to the west and the melting chamber (the floor) to the east (Tal *et al.*,2004: 56). The melting chamber measured 5m x 3.8m with a preserved glass floor at the centre with dimensions 2.3m x 2.3m. The western part of the melting chamber was damaged (Tal *et al.*, 2004:56). The firing area measured about 3.8 m x 1.6m and was less well preserved (Tal *et al.*, 2004:56). The installation of the furnace, which was possibly built upon an earlier one, was completed probably by local mud-bricks and some of the ashlars may have taken older buildings (Tal *et al.*,2004:56).The trial excavations revealed a large glass slab measuring about 4.45 m x 2.95m. As already mentioned large glass slabs are rare. The slab was similar to the one discovered at Beth She'arim (Tal *et al.*,2004:56). Once the slab was solidified and cooled it would have been extracted from the furnace to break into chunks of various sizes (Tal *et al.*,2004:56).The large amount of glass chunks suggests that the product of the factory was similar to the product of the other furnaces; high quality, with few bubbles, transparent blue and greenish blue raw glass (Tal *et al.*,2004:56). Nevertheless, a tinge of yellowish green and yellowish brown raw glass, owing to the absorption of oxygen, was found in the preserved corners of the melting chamber (Tal *et al.*,2004:57). Fragments of the Palestinian bag-shaped jar would place the construction of the furnace in the 6th century AD (Tal *et al.*,2004:57). But a later date is also possible.

Further excavations during 2006 at the southern part of the site revealed indirect evidence for a glassmaking workshop (Freestone *et al.*,2008:68). Architectural remains of a furnace were not uncovered but an enormous amount of raw glass chunks were found (Freestone *et al.*,2008:68). The only colour obtained was blue. The raw glass is contemporaneous, as the pottery vessels show, with the product of the other three furnaces and dated to the late Byzantine period (Freestone *et al.*,2008:68). A number of bowls, bottles, wine-glasses, cosmetic tubes, and lamp

bowls were also uncovered (Freestone *et al.*,2008:68). The assumption that a secondary workshop must exist in the site is probably erroneous as no moils or deformed vessels have been found at the site (Freestone *et al.*,2008:68). The southern section of the fourth furnace of the site was uncovered during the same excavations. The furnace was less well preserved. The floor of the furnace revealed raw blue glass. The construction of the furnace was similar to the furnace discovered in 2002. The similarity of the construction probably dates the fourth furnace to no later than the 7th century AD (Freestone *et al.*,2008:70).

In the centre of the Sharon plain at Bet Eli'ezer, Hadera, the best-preserved large primary glass production centre in Israel was found during the salvage excavation in 1992(Gorin-Rosen,1995: 52;Riklin,1998:55;Gorin-Rosen,2000:52;Tal, Jackson-Tal,Freestone,2004:59). The excavation was carried out for the preparation of building a road, and with the purpose to preserve the ancient Byzantine site from the winter floods (Gorin-Rosen,1995:42). The site, located between the foothills of Samaria and the coast, was ideal for the development of glass manufacture due to its proximity to the raw materials and fuels (Gorin-Rosen,1995:43,Gorin-Rosen,2000:52;Tal, Jackson-Tal,Freestone,2004:59). The remains of seventeen primary furnaces with firing and melting chambers of high technological level, were uncovered at the area with the old Arabic name "Zeita- Gazaza" (Gazaza means glass in Arabic) (Gorin-Rosen,1995:42;Riklin,1998:55-56). Portions of tank floors covered with a thin coating of glass were discovered at the area and a few walls of the furnaces (Gorin-Rosen,1995:42). Nevertheless, all the furnaces were found destroyed (Gorin-Rosen,1995:42). The furnaces should be dated to the Late-Byzantine- beginning of the early Islamic period as the pottery and glass finds show (Gorin-Rosen,1995:43). Bet Eli'ezer could have manufactured several hundred tons of glass as each furnace could possibly produce eight to ten tons of glass in a single firing at a temperature of approximately 900° C (Gorin-Rosen,1995:42;Aldsworth *et al.*,2002:203). The glass was of excellent quality, transparent (in various shades of green, blue, greenish blue, yellowish green and yellowish brown) with few bubbles and impurities (Gorin-Rosen,1995:43). Remains of 25 kg of small glass chunks of various sizes that were apparently kept in baskets or sacks were found in the area and no remains of glass vessel manufacture were identified (Gorin-Rosen,1995:42). The small amount of the chunks probably shows an effort to enable maximum production rates (Gorin-Rosen,2000:52).

The Bet Eli'ezer furnaces had a rectangular tank measured four metres long and two metres wide with a trapezoidal furnace of two firing chambers (Gorin-Rosen,1995:42). Mud-bricks, with dimensions 10x10x30 cm, that were made probably locally, were used for the construction and the roof installation. The tank furnaces, in order to extract the raw glass, were dismantled after the manufacturing process that probably lasted up to two weeks (Gorin-Rosen,1995:42). It is

assumed that the same baked mud bricks were reused again to build new furnaces (Gorin-Rosen, 1995:42). The pattern of construction of the furnaces was on the east-west axis with the firing area to the west, in order to utilize the seasonal winds for air circulation essential to the process (Gorin-Rosen,1995:42;Gorin-Rosen,2000:52). The set-up of the foundation of the furnaces to make raw glass must have taken place at the end of the spring so as the swamp would be dry enough (Gorin-Rosen,2000:52). The mud bricks and the raw materials were also prepared in the period (Gorin-Rosen,2000:52). The wood that the glassmakers burned in the heart of the kiln would be cut in the summer period and dried in order to obtain high enough temperatures reaching 1100 ° C, to make the kiln work properly and keep a smokeless fire burning (Gorin-Rosen,2000:52). The manufacturing process at Bet Eli'ezer began at the end of the summer, because of the glassmakers' efforts to use the south-west winds, and lasted probably only one or two seasons. The tank furnaces required large quantities of fuels and the fuels were quickly exhausted. Then the manufacturing process began again in another location in the same area near the woods and the raw materials (Gorin-Rosen,2000:52).

East of Bet Eli'ezer, at a distance of c.7 km, surveys and salvage excavations at Ḥorbat Biẓ'an unearthed numerous glass production remains (Gorin-Rosen,2012:49). The remains of the glass vessels (multiple trailed decorated bottles, bowls with in-folded rims, bowls with high, tubular ring bases, bottles with out-folded rims, wineglasses with tubular bases) were dated to the late-Byzantine and early Umayyad period (Gorin-Rosen,2012:52). Raw glass furnaces or the floor of the furnaces were not found but the remains suggest that a raw glass furnace or furnaces were located nearby (Gorin-Rosen,2012:49). Area A revealed raw glass chunks, debris from primary furnaces and glazed bricks (Gorin-Rosen,2012:49). The glazed mudbricks, based on their similarity with those found at Bet Eli'ezer, could be from the wall of a raw glass furnace (Gorin-Rosen,2012:49). The glazed mudbricks and the absence of obvious glassblowing remains might attest to glassmaking in the area but lacking other evidence such as a furnace with the melting or the firing chamber or the floor, it is impossible to deduce whether this is a primary or secondary production stage (Gorin-Rosen,2012:49).

On the western edge of the Jezreel Valley, south of Apollonia –Arsuf, glassmaking activity was recognized at Beth She'arim (Brill,1965;Vitto,1991;Gorin-Rosen,2000; Freestone, Gorin-Rosen, 1999). Beth She'arim was a settlement that existed since the Iron Age II, continued throughout the Persian and Hellenistic periods and after a period of decline and retrenchment probably enjoyed a second period of prosperity during the Byzantine period (Vitto,1991:137;Freestone, Gorin-Rosen,1999:113). The settlement was an important centre of Jewish learning and an important burial centre for Jews (Vitto,1999:137).The excavations conducted in the 1950s at

Beth She'arim uncovered several catacombs carved into the limestone cliffs of the area (Brill, Wosinski,1965: 219.1). In the midst of these catacombs a sizable underground cistern was found which was probably formed by enlarging a natural cave (Brill,Wosinski,1965: 19.1). The cistern was likely to have functioned during the Byzantine period. The silted up cistern revealed a huge rectangular slab of glass, where it had been melted in a tank furnace and then left there to cool (Brill,Wosinski,1965: 219.1). The assumption is that the slab is from the post-Byzantine period since it is impossible that the glassmaking industry could have functioned within a cemetery (Freestone,Gorin-Rosen,1999:113). At the time of its discovery, the excavators Avigad and Mazar noted that the find in a tomb context suggests that the slab was dated after the religious significance of Bet She'arim came to decline (Vitto,1991:140). However, the poetical lament in Arabic dated to 902 CE attests that the Jewish pilgrims visited the necropolis during the ´Abbāsid period (Vitto,1991:141). The slab must have been an attempt of Jewish glassmakers to marry the raw materials from the Roman-Byzantine tradition with a new material, plant-ash (Freestone, Gorin-Rosen,1999:116). The fact that the glassmakers at Bet She'arim used the eastern glassmaking traditions introduced by Islam (using the plant-ash as an alkali source), in combination with the fact that natron became difficult to obtain, might have driven the glassmakers to search new local raw materials produced by burning plants.

The slab measures 3.40 metres by 1.94 metre, and averages about 45 cm (Brill,Wosinski,1965: 219.1). Its total weight can be calculated as 8.80 tons. The most noteworthy feature is exactly its size as it is one of the largest pieces of glass ever found during excavations (Brill,Wosinski,1965: 219.1). The slab had gone unnoticed for a long time in the cistern that was converted into a small museum until 1964 when the Corning Museum of Glass, University of Missouri Expedition, decided to examine the slab (***Figure, 2.3.2.2***, http://www.simchajtv.com/temple-glass-discovered, Brill,Wosinski,1965:219.1). The analyses show that it was homogenous soda-lime silica glass with evidence of weathering of ancient fractures caused by inadequate annealing and differences in the thermal expansions of the glass and devitrification crystals (Brill,Wosinski,1965:219.3). The vexing problem with the slab was the enormous high lime content approximately double the lime contents of the ancient glasses (Brill,Wosinski,1965:219.5). Consequently, the slab was not similar to the glass from Roman, pre-Roman, Byzantine and Islamic times (Brill,Wosinski,1965: 219.2;Freestone,Gorin-Rosen,1999:112). Thus, it was difficult to be say virtually anything about the exact age of the slab.

But the most recent careful examination completely changed our view about the date and the raw materials of the slab (Freestone,Gorin-Rosen,1999:112). Freestone and Gorin-Rosen suggested that the raw materials of the slab were probably silica-lime-plant-ash glass because of



Figure 2.3.2.2: *Rectangular glass slab at the front in the small museum with a plaster architectural model on the top (http://www.simchajtv.com/temple-glass-discovered).*

the high levels of potash and magnesia and not soda-silica-lime as previously believed (Freestone, Gorin-Rosen,1999:112). But all these are characteristics of the glasses of the Islamic period (Freestone,Gorin-Rosen,1999:112). The content of the manganese oxide also shows an Islamic date because it was similar with the Islamic glass that came from Banias (Freestone,Gorin-Rosen,1999:113). In the Islamic period (especially after the 8th century AD) manganese was added deliberately, fired under oxidising conditions, to colour the glass purple (Freestone,Gorin-Rosen,1999:113). The examination of the Corning Museum of Glass actually shows that the slab was generally a purplish colour from top to bottom, with exception of a vein of a greenish colour running through the centre (Brill,Wosinski,1965:129.3).

The furnace where the raw materials were fused was a large tank probably of the type characteristic of the earlier natron glassmaking tradition (Brill,Wosinski,1965: 219.10;Freestone, Gorin-Rosen,1999:16). The tank furnace was not part of a group of furnaces as was very common during the early Islamic period. In contrast it was isolated in a cave that might suggest a degree of secrecy (Freestone,Gorin-Rosen,1999:16).The excavators Avigad and Nagar added that normally such a large-scale process would be unlikely to have taken place in a cave but in or near a busy community (Vitto,1991:140).The tank furnace may have been made by limestone blocks

or from local rocks (Vitto,1991:139). It would probably have had a lining of clay fired on (Brill, Woskinski,1965:219.10). The temperature obtained in the furnace was not high enough as the Brill analyses show a large proportion of the gases remains dissolved in the slab (Brill,Woskinski, 1965:219.6). Brill stated that the heating was in excess of 875° C and the liquids of the slab glass should be about 1130° C (Brill,Woskinski,1965:219.11). More recently, Freestone and Gorin-Rosen, examining the slab more carefully, observed that the glass must be heated only to around 1050° C (Freestone,Gorin-Rosen,1999:112). But if the soda-lime-silica slab was kept at such temperatures for a sufficient period of time it would have undergone complete melting (Freestone,Gorin-Rosen,1999:112). But why did the slab fail to melt completely? A possible explanation for the failure of the slab was its unusual composition (abnormally high lime content (Brill,Woskinski,1965:219.11,Freestone,Gorin-Rosen,1999:112). Brill proposed that the content was not basically deliberate and the high lime content was a result of refractory corrosion or drop-down from the furnace ceiling, causing the spoiling overdose of the ingredient (Brill,Woskinski,1965:219.11). Another assumption was that the high content caused the raw material impurities if the glassmakers were tempted to use a closer source of sand than the pure sand from the beach 20 kilometres away (Brill,Woskinski,1965:219.11). The excavator Avigad on the other hand suggested that the glassmakers who needed large quantities of lime broken into pieces may have smashed the marble sarcophagi decorated with mythological scenes and pagan figures found in Catacomb 20 in order to serve as raw material for lime (Vitto,1991:137). Nevertheless, a more detailed understanding of the reason of the high lime and its failure given by Freestone and Gorin-Rosen suggested that the Bet She'arim slab was made by mixing two materials rich in lime, the plant-ash (used by Islamic craftsmen but with a lime-poor quartz) with a shell bearing sand (used by Byzantine craftsmen but with a lime-poor natron) (Freestone,Gorin-Rosen,1999:115).

The failure was due to the incompatible combination of the Belus-type sand with the plant ash (Freestone,Gorin-Rosen,1999:116). Based on the plant ash and in manganese, Freestone and Gorin-Rosen dated the slab to about the early 9th century A.D. or later (Freestone,Gorin-Rosen, 1999:116). The result of the failure was very poor quality glass that was not heavily devitrified, highly strained, and not very homogeneous (Brill,Woskinski,965:219.2). Sizable chunks have been broken away probably to provide raw material and transported to other places for remelting, or to be used there for architectural or ceremonial purposes (Brill,Woskinski,1965: 219.2).Thus, it seems that if that was a product of a glass factory it certainly contributed to the prosperity of the Bet She'arim (Vitto,1991:140).

2.3.3 Glassmaking workshops during the 8th century AD

The archaeological evidence on the Levantine coast shows that the Islamic glass makers until about the end of the 8th century AD had relied upon 'Byzantine' expertise for the production of raw glass using local sand and imported natron (Gorin-Rosen,1995,42-3,2000;Freestone *et al.*, 2000,67;Henderson *et al.*,2009:414). After AD 800, the emergence of a strong Islamic cultural identity brought new technological procedures (Henderson *et al.*,2009:416). Muslims used tank furnaces to make plant-ash glass using various soda-rich halophytic plants (Henderson *et al.*, 2009:414). The best evidence for plant ash glass manufacturing, over a period of c. 400 years, comes from al-Raqqa (Henderson1995;Henderson,1999;Henderson *et al.*,2005). The scientific analysis of glass from al-Raqqa demonstrated a phase of earlier experimentation (25 years earlier) there before AD 845 when a new alkali source had been documented in Egypt (Henderson *et al.*, 2004:458;Henderson *et al.*,2009:427).The transitional glass composition led to the assumption that al-Raqqa was one of the locations of which its glass technological change affected the entire Islamic world (Henderson,1999b:238).

Al-Raqqa, in northern central Syria, located closed to the junction of the river Euphrates and its tributary the Ballkh, was the ´Abbāsid court of caliph Hārūn ar-Rashīd between AD 796 and 808 (Henderson,1999:243). From the mid-8th century onwards al-Raqqa became a protective garrison and thus an important centre (Henderson,1995:434;Henderson,1999:243). The caliph built the city ar-Rāfiqa, next to al-Raqqa, with one industrial and twenty palatial complexes. The palace complexes were excavated between 1982 and 1993 by Michael Meinecke (Henderson,1999:244). The excavations uncovered the remains of a glass atelier of the late 8th –early 9th century AD in a suburb known as Mishlab (Henderson,1995:434). The atelier was contemporary with five of the twenty palatial complexes (Henderson,1995:434). The glass manufacturing remains had been thoroughly investigated later (1992-1993) by Henderson and Becker (Henderson,1999:244). One year later the excavations became the project of the British Archaeological Mission to al-Raqqa and have focused on three tells, Tell Zujāj (dating to the late 8th-9th century AD), Tell Fukhkhār (dating to the 11th century AD) and Tell Abū ʾAlī (dating probably to the 9th century AD) (Henderson,1999: 245;Henderson *et al.*,2005).

The craft of glassmaking was identified in al-Raqqa together with a range of pyrotechnologies (Khalil,Henderson:2011). The excavations proved helpful to ascertain information on glassmaking in contradistinction with those technologies, such as ceramic and metal technology.

At Tell Fukhkhār glassmaking was identified together with possibly enamel production and with iron and copper alloy. Later during the excavations in 2010 the craft was identified together with pottery glazed production at Tell Abū ʾAlī (Khalil,Henderson:2011). The glassmaker, probably dependent on shared fuels or raw materials between metal and ceramic production could possibly work together and exchange technological information with a potter or glassworker or with a craftsman who handled metals. Since the exercise of the glassmaking craft required essentially the pyrotechnological technical know-how, to obtain maximum temperatures for the operation of the furnaces, one might be able to think of the glassmaker as an itinerant artisan producing glass under special circumstances. Al-Raqqa's excavations attracted considerable attention mainly because the site was the only place in the Islamic world that produced evidence both for primary and secondary glass production. At Tell Zujāj a large number of raw glasses were uncovered together with hundreds of ʾAbbāsid glass vessels fragments, rods of glass, pulls of glass, dribbles, and drops of glass but nevertheless specific evidence for enameling has not been uncovered (Henderson,1999:256).

By utilizing the archaeological information from al-Raqqa excavations it is evident that, although large tank furnaces were recovered in the Middle East, there were still workshops during the early Islamic period that used earlier traditional methods of two or three stages of melting of the raw materials. Because of the absence of the large tank furnaces in the middle phase it seems that two stage process took place in al-Raqqa. The reasons for the selection of an old-fashioned technique are various. The selection may indicate a desire of a glassmaker to continue a method dated to a long past era or a desire to reduce the quantity of fuels, or to reduce the volume in the furnace, or to work the furnace at lower temperatures below 1250° C (Henderson,2013:273). The two or three stages were an economical and faster process because the glassmaker could accelerate the process by adding cullet (broken glass), the waste of the glasshouse. Technologically the two or three staged process consists of repeated heating, melting and cooling off the basic materials and adding specific ingredients at certain points to serve as a colorant or opacifiers. The first stage was called fritting and yields the product called frit. Frit is a chemical intermediate, a manufactured substance to be used as a starting material for the other one or two manufacturing processes that followed (Turner b,1956:293;Brill,1970:109;Henderson,1999: 258).

The manufactured product of fritting was a base glass from sand or quartzite pebbles with natron or plant ash. The chemical reaction of both those materials was the most difficult step of fritting (Brill,1970:109). For that purpose, the suitable materials had to be found first. It is still uncertain if purification of the raw materials by selection, and in the case of ash by solution, filtration and

evaporation was carried out (Turner b,1956: 293). But it was certain that the raw materials were ground to a small size (Henderson,1985:270). The quartzite pebbles certainly had been ground to a powder (Brill,1970:112). After grinding finely, separately, the batch materials were weighed and then thoroughly mixed; then heated in a cold furnace at a moderate temperature, above 750°C at about 900°C creating gaseous products (Brill,1970:113). The furnace would have had fire openings where the mixture was arranged between the openings. The mixture would not have been allowed to liquefy (Biek,Bayley,1979:1).The fritting temperatures were so low that the way to the reaction of the sulphides with the sand was still closed (Turner b,1956:294). The way was opened at the second stage, when the fritting process had finished (Turner b,1956:294). The heating in the second stage of melting would have been at temperatures of at least 1050-1100°C in reasonable time. The second stage was essential for the removal of the gaseous bubbles produced in frit by the breakdown of the carbonates, sulphides and sulphates (Henderson,2013: 274).

Nowadays experimental archaeology and ethnographic parallels show unexpectedly that high quality glass, with few bubbles and traces, could have been produced without the need for the initial stage of fritting (Brill,1970:113;Jackson *et al.*1998:22;Sode,Kock,2001:157). The furnaces were usually two, but sometimes there were three, depending on how many the glassmaker could use. The first furnace with a wood combustion chamber (wood was burned into the lowest compartment) was for fitting (melting the raw materials), the second, if it was used, to re-melt the frit again and the third an annealing chamber for the cooling and the glowing glass (Hasson,1979: 3;Freestone *et al.*, 2003: 22). The raw glass had to cool gradually to avoid stresses (Hasson,1979: 3). The whole process ended when the melted batch become viscous and extremely ductile (Jenkins,1986:3).

The manufacture of raw glass was identified at three tells in al-Raqqa. The most important was the Tell Zujāj because it was entirely relatable with the craft (Henderson,1999:256). Three different phases with glassmaking industrial installations and associated structures were revealed. The earlier phases were the most important (Henderson,1995:435). Four rooms of a hypocaust have been found at the early phase (Henderson,1999:252). A glass workshop could be installed in the deepest room of the hypocaust. Brick pilae being set at two different heights and with two different alignments were found (Henderson,1999:256). To the north-west an oval-shape hypocaust furnace was discovered with a tile floor at a height of 1.2m (Henderson,1999:252). The glass furnace had a sub-triangular wall at the south that might have been connected to the flue system. It would have been impossible to obtain high enough temperatures for the melting of the glass only by the hypocaust heating system (Henderson,1999:252). The floor of the

hypocaust has been robbed so there is no archaeological evidence that shows channels of the furnace linking to the glass workshop (Henderson,1999:252). The phase is dated earlier than AD 804 according to the ´Abbāsid wares and to copper alloy coins (Henderson,1999:256). A second glass workshop with three furnaces of the 'southern' type (each with three chambers) was discovered in the middle phase (Henderson,1999:251). The Ἀbbāsid glazed and unglazed pottery dates the furnaces to the period of the installation of Hārūn ar-Rashīd in al-Raqqa (AD 796-808) (Henderson,1999:256).

The furnaces, small with a diameter of c.25cm, were built against the walls of the hypocaust and faced towards the centre of the room (Henderson,1999:248). Holes have been constructed below the floor level (Henderson,1999:248). Those holes must have supplied fuels to the furnaces. A forced draught was presumably provided by a set of bellows and tuyéres to keep a temperature of at least 1200 °C (Henderson,1995:435;Henderson,1999:249). The construction of the furnaces was with bricks luted with clay (Henderson,1995:435;Henderson,1999:249). All the furnaces contained a fill of soot, charcoal, bone fragments, ash and highly baked clay (Henderson,1999:249). At the south–east corner of the workshop the first furnace was found (Henderson,1999:247). The furnace must have been a bee-hive structure with three chambers disposed one above the other (Henderson,1999:247). The top chamber had a clay dome roof, part of which was still retained at a total weight of 1.3 metres (Henderson,1995:435, Henderson,1999:247). The function of the upper chamber was probably to cool vessels after their manufacture (Henderson,1999:247). Directly on the back of the furnace there was a semi-circular structure used also as an annealing chamber (Henderson,1999:247).

The melting chamber was the lower chamber where fuels were placed. The heat presumably had risen from down to heat a pot (crucible) where glass was located. Remnant sections of the floor of the chambers survived (Henderson,1999:247). At the north-east a second furnace was found, constructed with reference to the solid wall of the hypocaust (Henderson,1999:248). At the north-west a third furnace was discovered, the same as the construction of the others. The fourth furnace was a structure with a chimney connected to it and it was found at the south-west corner (Henderson,1999:250). The central chamber of all the furnaces must have had at least one opening where a gathered iron removed the glass from the crucibles (Henderson,1999:250). The furnace floors were constructed with bricks and had been robbed (Henderson,1999:256). The bricks had been damaged by intense heat (minimum temperature 1,200° C (Henderson, 1999:256). Large numbers of melted bricks with glass adhering to them were found all around the workshop (Henderson,1999:256). Beneath the floors there must have been channels leading to the firing chambers (Henderson,1999:250).

The late phase provides structural remains of destroyed tank furnaces that were producing glass in one firing (Henderson,1999:263). The furnaces were located at the south-east corner and must have been dumped into pits (Henderson,1999:263). The evidence was patchy (Henderson, 1999:256). Only the brick from the furnaces survived. The bricks were extremely black and melted as the result of the intense heat. The excavations revealed one furnace floor partly destroyed (Henderson,1999:246). Beside the plastered floor two small vitrified structures and a pit were found (Henderson,1999:246). The structures presumably functioned as a fritting oven (Henderson,1999:246). Evidence of fritting (grey semi-vitrified material) was found at the late phase. The pit was pear-shaped and functioned presumably as a lower chamber of a glass furnace (Henderson,1999:247). Many glass fragments, charcoal and burnt bones have been found inside the pit. The pit was robbed but the remains of mud-brick wall foundations were saved, as well as copper alloy coins and pot sherds with Arabic writing on them (Henderson,1999:247). One sherd of Sāmarrā lustre ware dates the phase into the 820 A.D. Tons glassmaking debris was found at several pits (Henderson,1999:255). The large amount of debris suggests the existence of several destroyed furnaces that unfortunately were not uncovered during the excavations (Henderson,1999:247). The product of the furnaces was blocks of glass of three different sizes. The excavations revealed the large trays with glass adhering to them where the blocks were casting into (Henderson,1999:257,Henderson1999:256). It seems that the large blocks acted as a material for the construction of floors and the smaller as tesserae.

In the following years the investigations were focused on Tell Fukhkhār and Tell Bellor. The craft of glassmaking was recognized along with pottery and iron production at the first mentioned tell. The excavations of1995 and 1996 revealed a large amount of refuse from pottery and iron production (Henderson,1999:261). Among the debris weathered and redeposited fragments of a glass furnace and lumps of raw glass were found. The second tell, located at the centre of al-Raqqa al-Mutariqua, was excavated for three seasons in an area 8x8m (Henderson *et al.,*2005: 136). The ground surface revealed industrial debris of glassmaking. Below the ground surface two sub-rectangular structures was found, glass debris and frit at the depth of 0.15m (Henderson *et al.*,2005:136). The structures, measuring 0.05-0.10m in depth, probably functioned as fritting ovens (Henderson *et al.*,2005:136). Below the fritting ovens a clay surface measuring 2x5m was uncovered (Henderson et al.,2005:136). The surface was cut away to the north-east and revealed large fragments of a glass furnace floor, glassblowing waste and frit (Henderson *et al.*, 2005:136). The first in-situ rectangular glass tank furnace was excavated at Tell Abu Ali at the northern edge of Mishlab during the four week excavations in 2010 (***Figure 2.3.3.1.***,Khalil,Henderson,2011:239).

The furnace was part of the industrial workshops extending to Mishlab during the ʿAbbāsid period (Khalil,Henderson,2011:242). The exact dimensions of the furnace are still unknown because it was found damaged. But it is estimated that it measured 3.7x 2m (Khalil, Henderson,2011:237). The alignment of the furnace was northeast to southwest (Khalil, Henderson,2011:237). At the southeastern end a wall of the furnace and two courses of floor were recovered. It seems that the floor was made with slabs as the straight vitrified ridges attached to the wall shows (Khalil, Henderson,2011:238). The slabs, with glass adhering to them, had a different size (Khalil,Henderson,2011:239). The floor was distorted and sloped upward to the north (Khalil,Henderson,2011:240). Two successive walls, constructed so that one wall protected the other from the intense heat, were found at the west of the furnace. Against the western wall a mud brick structure was found with at least three holes. Through those holes a forced draft was introduced into the furnace, probably with tuyères and bellows (Khalil,Henderson,2011:240). The nature of the firing chambers is still unknown. Below the floor of the first phase a chamber containing fuel (fine charcoal fragments and olive pips) was found.

The chamber of the first phase was presumably the melting chamber of the second phase (Khalil, Henderson,2011:240). It seems that the furnace was a downdraft type (the heat was drawn upward) with a specific mechanism (Khalil,Henderson,2011:240). The furnace must have been covered by a 'barrel-vaulted' structure and the roof must have been tunnel-shaped although no evidence of the roof was found (Khalil, Henderson,2011:241). The raw materials of the furnaces were a mixture of glass and frit or a mixture of glass, sand and halophytic plant-ash (Khalil, Henderson,2011:242). The discarded remains of the primary raw glass obtained only four colours green, purple, colourless and blue (Khalil, Henderson,2011:238). The deep purple and green raw glass were found at a second possibly glass furnace. The furnace was either circular or an apsidal-ended tank furnace (Khalil,Henderson,2011:241). It was similar in construction to the previous furnaces. The floor was made from two courses of bricks and slabs. Glass of green and purple colour found adhering to the floor suggested that the furnace was used for the melting of raw materials (Khalil,Henderson,2011:242).

The exceptional discoveries in the early 1990s of the melting tank furnaces on the Levantine coast and in northern central Syria led the researcher Marie-Dominique Nenna to try to identify primary structures in Egypt. The glass industry in Egypt was the most extensive and long-established industry among the industries in the Levantine cities of Tyre and Beirut (Carboni *et*



Figure 2.3.3.1.: *The rectangular tank glass furnace at Tell Abu Ali (Khalil,Henderson,2011:239).*

al.,2003:141). For several centuries Egypt produced high quality glass. Thanks to the Hebrew documents discovered at the end of the 19th century in a storeroom in the Ezra Synagogue in Fusṭāṭ (near Cairo, in Lower Egypt) the researchers have a view of glass, glassmaking, glass commerce and the social status of the glassmakers (Carboni *et al.*,2003:141). References to the Levant superior quality glass are scarce while the great majority refers to Egypt and Fusṭāṭ (Freestone,2006:202). The improved technology of chemical analysis of Egyptian glass of the Islamic period from Fusṭāṭ and of official glass weights issued at Cairo suggested that a range of soda-lime-silica glasses were produced in the Islamic world and even in Egypt itself (Scanlon, 1981:243). Nevertheless, primary workshops producing glass were never found at the archaeological excavations in Egypt until 1996.

New excavations in Egypt in the Alexandria area and in Wadi Natrun since 1996 have uncovered several glass melting furnaces with large tanks dating, on one hand, to the early Caesarean Era and, on the other, to late antiquity (Nenna,2003:59). Five sites with primary workshops were identified, two in Mareotis at Taposiris Magna and Marea Philoxenite and three in Wadi Natrun in Beni Salama, Bir Hooker and Zakik (Nenna,2003:59). West of Alexandria in lake ports Taposiris Magna and Marea-Philoxenite two primary workshops were located (Nenna et al., 2000,102). These primary workshops were active in the late Roman period and the Marea-

Philoxenite between the 5th and the beginning of the 8th century AD (Nenna,2003:59). The workshops have been found at the ancient freshwater lake Mariut close to the sea. Mariut lake was important for the trade with Alexandria and its rich port is highlighted by Strabo (Nenna *et al.*,2012:102). The craft of glassmaking was recognized along with ceramic and metal activity at Taposiris Magna dock. During the excavations were found waste flows dismantled furnaces date to the Ptolemaic period and fragments of the furnaces walls dated from the beginning of the imperial period until the 5th and the 6th centuries AD (Nenna *et al.*,2000:103). On the site usually called Marea two vestige primary workshops were located (Nenna *et al.*,2000:103). Marea was known in the Pharaonic and Greco-Roman period but the site was not identified. The excavations at the settlement have uncovered several glassmaking remains dating to the period between the 5th and the 8th century AD (Nenna *et al.*,2000:103). To the west of the city one workshop was located and to the east a second. The workshop to the west revealed a small number of fragments of a dump of a primary workshop. Nevertheless, architectural structures related to glassmaking and ancillary structures were not uncovered during the excavations (Nenna *et al.*,2000:103). The second workshop does not reveal an oven, only a round installation of brick and limestone, although the large amount of bricks with glass adhering to them suggests the existence of a primary workshop (Nenna *et al.*,2000:103).

2.3.4 Glassmaking workshops after the 8th century AD

North of the Israel-Lebanon border glassmaking activity has been established at Tyre (Aldsworth *et al.*,2002;Carboni *et al.*,2003:141). Tyre during the early Islamic period was a commercial city with a very famous harbour. The extensive excavations in the late 1940s and 1950s at the prosperous roman city (devastated by earthquake in A.D. 551) brought evidence at the main colonnade of post-Roman raw glass production (Aldsworth *et al.*,2002:49). South and west of the colonnade a glassmaking complex was found that was built around a fallen granite column which collapsed during the earthquake and up to a white marble floor (Aldsworth *et al.*,2002:49). North and west of the colonnade a large amount of glassmaking debris was uncovered (Aldsworth *et al.*,2002:49). It is difficult to date the glassmaking complex precisely as no coins were found (Aldsworth *et al.*,2002:65). The dating evidence is limited and comes only from an amphora of the 9th century found on one furnace floor and from glazed fragments of the 10th and 11th centuries found in the debris of one furnace (Aldsworth *et al.*,2002:65). The chemical analysis of the glass finds dated the operation of the factory after the 8th and 9th century AD, as the main

source of alkali was the plant-ash (Aldsworth et al.,2002:65). Four furnaces together with structures associated with the making of raw glass were uncovered at the glass factory that measured probably 28.70 metres from east to west (Aldsworth *et al.*,2002:51). The furnaces (built within the wall of the existing buildings) were of reverberatory type (the heat is drawn up and over the raw materials) and consist of two parts: the firing chamber and the melting chamber containing an open-top mortar-lined tank (Aldsworth *et al.*,2002:51). Extraction of the raw glass from the tank would have removed the upper part of the tank floor (Aldsworth *et al.*, 2002: 64). The four furnaces, not very well preserved, were variable, with different orientation but with several features in common (in the construction and the way in which they were used) (Aldsworth *et al.*,2002:62).

The first furnace was the largest and the only one that brings unequivocal evidence of glassmaking in the two long walls (Aldsworth *et al.*,2002:51). The furnace was oriented at the east-west axis with the firing chamber probably at the east and the melting chamber at the south. The firing chamber did not survive because the area was heavily disturbed. The excavation uncovered only the base of the mortar-lined melting chamber. The base of the chamber was rectangular (Aldsworth *et al.*,2002:51). Part of a loading floor of the furnace, measuring 6.40 by 3.90 metres, and walls with mortar linings were also uncovered (Aldsworth *et al.*,2002:51). The tank floor, measuring 6.40 by 3.90 metres, was a slightly concave rectangle (Aldsworth *et al.*,2002:51). The upper part of the floor was pitted with a fissured surface for the removal of glass (Aldsworth *et al.*, 2002:53). Chamfered stones with sloping surfaces were found both at the western and eastern end of the tank (Aldsworth *et al.*,2002:53).

The furnace was inserted within two pre-existing parallel stone walls, with the south side built directly against the southern boundary wall while the north side built with earth and rubble fill between the linings and the wall to provide insulation against heat loss (Aldsworth *et al.*,2002: 53). Successive linings can be observed both at the south wall of the furnace and at the east end (Aldsworth *et al.*,2002:53). Attention has to be drawn to the inner surface of the lining found at the south wall and at the west end corner. The entire surface of the south wall, 0.80 metres high, was coated with a green glass presumably the last melt of the furnace (Aldsworth *et al.*,2002:54). The green glass of the western corner had three layers of matte light brown to grey colour due to devitrification (Aldsworth *et al.*,2002:54). West in a shallow depression that was running north-south a very hard surface of buff to light grey mortar was found containing small pebbles, small lumps and chips of glass. The surface presumably served as a floor for the collection of the volume of the required raw materials (Aldsworth *et al.*,2002:54). The furnace was in use at least

three times but its final melting was a failure (Aldsworth *et al.*,2002:66). Then the furnace was abandoned (Aldsworth *et al.*,2002:64).

The most complete furnace retrieved during the excavations was the second furnace. Furnace 2 was built on the same alignment (east-west) as the first furnace but having the firing and melting chamber at the opposite site (Aldsworth *et al.*,2002:55). The firing chamber, similar to those found at Bet Eli'ezer, was also located at the west end. The one chamber had to be raked out while the second was still heating the melt (Aldsworth *et al.*,2002:63). The chambers had internal dimensions 2.68 by 1.12 metres (to the north) and 2.64 by 1.3 metres (to the south). The stones of the firing chambers show signs of extreme heat especially at the end of the tank (stones badly cracked) (Aldsworth *et al.*,2002:58). The original floor of the firing chamber was not found but the floor of the melting chamber was found almost complete (Aldsworth *et al.*,2002:58). The floor was rectangular and measured 4.50 by 2.20 metres (Aldsworth *et al.*,2002:55). Located to the west, the floor was constructed of mortar with small pebble inclusions. At the junctions of the floor and the walls stones with chamfered edges were found (Aldsworth *et al.*, 2002:55). The melting chamber had been removed to the east but its south wall extends some 3.50 metres (Aldsworth *et al.*,2002:59). The construction of the south wall was two faces of rectangular stones and at the north edge shows patches of hard mortar spread with small glass chips (Aldsworth *et al.*,2002:59). The furnace was inserted within the two parallels walls of an existing building (Aldsworth *et al.*,2002:55). The southern side of the tank had been directly constructed against an existing wall while the northern side had soil and rumble packing between the mortar lining and the existing wall (Aldsworth *et al.*,2002:55). The furnace was in operation at least two times because traces of mortar surface show that it was relined at least once (Aldsworth *et al.*,2002:55). Further west, traces of two furnaces were found at an area defined by the pieces of fallen granite column and by the west boundary wall (Aldsworth *et al.*,2002:59). The furnaces were found side by side at a different orientation to the previous furnaces situated at the north-south axis (Aldsworth *et al.*,2002: 63). The different orientation of all the furnaces found at Tyre show that the wind was either variable or unpredictable and that it could cause sudden fluctuation in the temperature (Aldsworth *et al.*,2002:63). The firing chambers were presumably to the west and would have faced inland (Aldsworth *et al.*,2002:63). The firing chambers were to the north but the previous excavations must have removed the north end of the furnace (Aldsworth *et al.*,2002:61). The furnaces, poorly preserved, were found astride the remains of an earlier wall. At the third furnace only a small part of the floor survives, consisting of patches of mortar (Aldsworth *et al.*,2002:59). The floor, 2.05 metres wide and approximately 3.90 metres long, was constructed with the same material but with an unusual makeup (Aldsworth *et al.*,2002:59).

Below the floor evidence of prolonged burning was uncovered, such as several deposits of small rubble and ash. How much glass was produced at the furnace is difficult to determine because the re-linings and the several episodes of the reconstruction show that the third furnace together with its adjacent furnace would have produced at least five melts (Aldsworth *et al.*,2002:66). At the highest point of the glass factory the fourth furnace was uncovered (Aldsworth *et al.*,2002: 61). The firing chamber or loading floor did not survive but only small pieces of mortar with many small chunks of mid-green raw glass were found (Aldsworth *et al.*,2002:66). Small patches of tank floor were found at the south end of the furnace (Aldsworth *et al.*,2002:66). The product of the furnaces was high quality transparent glass with few impurities and bubbles (Aldsworth *et al.*,2002:64). The glass evidence that survived in the furnaces was limited but the excavations show that at least four colours of glass were made at the site (green of different hues, decolorized, purple and cobalt blue) (Aldsworth *et al.*,2002:64). The predominant colour was the green and the decolorized as the amount of the large lumps and small pieces found at the site show (Aldsworth et al.,2002:66). The small quantity of blue glass is evidence that this kind of glass was produced in smaller quantities perhaps in a smaller furnace (Aldsworth *et al.*,2002:66). The least was the purple glass as only a few pieces were found (Aldsworth *et al.*,2002:66).

Surveys and further investigations in principal urban centres in Egypt, Syria and southern Mesopotamia can prove in the future the existence of primary glass workshops. The royal Samārrā was the capital of the ΄Abbāsid caliphate and a centre with wide ranging industrial activities. Given its industrial activities it is impossible that the craft of glassmaking was not active there. In 1987 a centre for glass production was revealed during surveys by Northedge and Faulkner close to Samārrā palaces and on the north bank of the river Tigris in an area known locally as m'mal al-Zujāj (Zujāj is an Arabic word for glass) (Henderson,2013:267). Evidence such as furnaces or ancillary structures associated with glassmaking was not uncovered there. Nevertheless, the large amount of glass finds led the scholars Lamm, Carboni and Whitehouse to suggest that glass was produced there (Henderson,2013:267). Nishapur must have been another centre for glass manufacture. The excavations at Nishapur did not identify architectural remains or kilns (Kroger,1995:20). Only two large slabs were found at the northern edge of Qanāt Tepe mound. Nevertheless, the large amount of glass found is an indirect indication that some of the glass was produced locally. The location of the site and considering the fact that Nishapur was a stop on the Silk Road make this hypothesis even stronger. The recent excavations at wealthy ports on the coast of the Persian Gulf, Sīrāf and Baṣra, are of special significance because the ports were wealth and the wealth derived almost entirely from the network of trade with the products of Africa, India and China. Given the fact that Sīrāf and Baṣra were the most

significant ports of the early Islamic period and cities with industrial activities led the scholars to suggest that primary glassmaking workshops could exist there. The discovery of new glass workshops in the Islamic world is a matter of chance.

2.4 Possible regional traditions of glass vessel production during the ´Abbāsid dynasty

The investigation presented in subchapter 2.4 is primarily concerned with regional traditions of specialist glass ateliers across a wide area of 2000 miles in the early Islamic empire. After the death of the prophet Mohammed in 632 AD, specialist glass ateliers following two diverse traditions, the great Roman legacy (Syria, Lebanon, Israel and Egypt) and the Sasanian tradition (Iran and Iraq), continue, without disruptions from the political changes, to melt chunks of natron (until 854 AD) or plant-ash glass so as to produce different types and forms of glasswares (Lukens, 1965;Kröger,1995:35;Gorin-Rosen,2000:63;Baker,2004:11;Henderson,2016:134;Henderson *et al.*,2016:142). There can be little doubt that those ateliers using distinct decorative techniques, such as lustre painting, relief cutting or scratch engraving, were producing high-quality glasswares for local use and export. But where exactly was that place where specific types, forms, and decorations occurred? The identification of the ateliers was one of the older problems of Islamic archaeology. So far, such an identification has been mere speculation, necessitated by the fact that, due to the universality of the style and the movement of the artisans, the decorative techniques were found in various regions of the Islamic empire (Lukens,1965:199,Saldern,1966: 10;Kröger,1995:36;Carboni,2001:4,Rogers,2005:19;Henderson,2013:254). In only a few instances, typology and the decorative technique, such as in the case of applied decoration, were helpful in proposing a geographic area with some degree of accuracy (Carboni,2001:164). It was necessary to apply scientific techniques, such as chemical and trace element analysis, to investigate early Islamic glasses and their regions.

In AD 632, the Islamic power rapidly expanded across the Near East, Palestine, Egypt, in regions of North Africa and Spain, and a new civilisation was created (Klein,Lloyd,2000,58, Henderson,2013:252). The Umayyads, the first Muslim dynasty, choose Damascus as their temporary capital from AD 661 to 749, and under their reign Greater Syria (modern Syria, Lebanon, Israel, Jordan, and Palestine) was established (Henderson,2013:253). Among the Islamic regions, Greater Syria had an illustrious history in glassmaking (Milwright,2014:201). Due to its availability of raw materials for glass production the region provided an unparalleled richness and variety of glasswares (Milwright,2014:201). The Umayyad caliphs seemed to highly appreciate glass, incorporating gilded glass mosaics into the construction of the Mosque at Damascus and of the five of the seventeen desert palaces, intending to give a shimmering and



Figure 2.4.1: Mosaic floor from Khirbat al-Mafjar Palace, at the time of al-Walīd (Tāhā,Whitcomb,2015: 115).

colourful effect (***Figure 2.4.1***,Wenzel,1986:217;Baker,2004:4;Walker2004:26). The audience hall in Qaṣr al-Ḥayr in Damascus yielded coloured glass and a single brown fragment painted in a yellow and blue enamel (dated to the 9th century AD) (O'Hea,2001:135). In the 1950s and 1960s, lustre painted fragments of similar character were found (Carboni,2001:52). These were a lustre painted cup and bowl, now in Corning and Damascus respectively, inscribed with the 'Damascus' in Kufic calligraphy (Ratliff *et al.*,2012:241):

بسم الله الرحمن الرحيم بركة من الله لمن يشرب بهذا القدح
مما صنع بدمشق على يدي سنباط [؟] في سنة [١]

'*In the name of God of Merciful, the Compassionate, God's blessing on the person who drinks from this cup, which was made in Damascus by the hand of Sunbāṭ (?) in the year I*' (Ratliff *et al.*, 2012:241)

Their inscription 'Damascus' (providing direct or indirect evidence) proves that Damascus must have been the place of their production (Carboni,2001:52). The question that readily arises is this: was the lustre-painted glass, or glass used in the mosaic decoration of mosques and palaces, produced in Damascus?

2.4.1 Damascus

According to the available archaeological evidence, Damascus was probably among the glassblowing centres that flourished in Egypt and Syria for the so-called lustre painted technique (Carboni,2001:52). This suggests that glassworkers in Damascus followed a sophisticated process in which spectacular glass objects were created by applying silver or copper stains (sulphide) on both sides of the glass vessels once their final shape was attained (Goldstein,2007:134;Carboni, 2004:51;Carboni,Whitehouse,2001:199). Following this initial stage, the next process was to put the glasses into a kiln and heat them at a low temperature (about 600 ° C) in a reducing atmosphere; the longer the paints were fired, the darker the glasswares become (Carboni, 2004:51). At this point the glasses were stained permanently because of the chemical reaction between the iron and copper ions (Carboni,2004:51;Goldstein,2007:134). As soon as the painted pigments were absorbed to a depth of a few microns, they were imperceptible to the touch (Pinder-Wilson,1968:101;Carboni,2004: 51;Goldstein,2007:134).

The lustre cup and bowl inscribed with the 'Damascus' in Kufic calligraphy have little artistic appeal, yet they have received special attention, mainly because they are two of the few examples of signed and dated glasses offering a clue about the place where the technique was practised (Kröger:1995:114). The first example was a cylindrical cup probably made in Damascus in the 2nd century AD (AD 718-815), based on a legible numeral 1 (***Figure 2.4.1.1***, Ratliff *et al.*, 2012:241,Carboni,2004:52). Looking at the inscribed cup, it can be observed that the calligraphic inscription was placed in a band; above the band were two narrow bands consisting of dots and V-shaped motifs (Carboni,Whitehouse,2001:201). The decoration of the cup with the small base and the flared walls consist of painted geometric and stylized vegetal patterns (Carboni,Whitehouse,2001:201). The base was decorated with a circle painted on the outside and a six-pointed brown star with a large dot in the middle painted on the inside (Carboni,Whitehouse,2001:201). The use of dots to fill geometrical areas is common on lustre from Damascus and Syria (Carboni,2004:54). The second example was a bowl found during the excavations in Raqqa; it is said that it was made in Damascus at the hands ('alā yaday [n]) of Sunbāṭ, a non-Arab, probably Greek or Jewish in origin, artist (Carboni,Whitehouse,2001:201; Carboni,2004:52;Baker,2004:11).



Figure 2.4.1.1.: *Lustre-painted cup now in the Corning Museum of Glass (Ratliff* et al.*,2012:241).*

The writing 'mimmā ṣuni 'a bi-Dimashq' below the rim of the cylindrical cup should attract special attention because, according to the researcher Goldstein, it literally means 'crafted in Damascus' (Goldstein,2007:134). When turning to the writing 'alā yaday [n] (from the hands of), there is a suggestion that the artist was a glassmaker and not just a painter (Carboni, Whitehouse,2001:202). It may be then tempting to suggest that Damascus was a place where glassmakers produced glass from its raw materials at least during the 11th and 12th centuries AD (Henderson *et al.*,2016:135). Evidence comes from the major, minor and trace element analyses conducted in 2016 (Henderson *et al.*,2016:135). The chemical analyses result of nine glasswares (beakers, a base, a body, a neck and a shoulder) found at Damascus show that the glasses were distinguished from other glasses produced in Greater Syria (Beirut and Khirbat al-Minya) (Henderson *et al.*,2016:142). In fact, glasswares from Damascus had a lower concentration of Cr/La and higher of Zr/Ti ratios (Henderson *et al.*,2016:142). Moreover, the above glasswares had the lowest Cs/K ratios in contrast with glasses that had the highest Cs/K ratios, moving from north (Beirut) to south (Egypt) (Henderson *et al.*,2016:142). The assumption is that glassmaking might have taken place earlier in Damascus. But whether Damascus was a glassmaking centre earlier than the 11th century AD is impossible to say. What can be argued, though, by the discovery of a lustre painted glass goblet with Egyptian provenance from American excavation at

Fusṭāṭ, is that Damascus and Syria were not the only places where lustre painting on glass was being practised. Here, an instructive parallel may be pointed out: the lustre glass cup found during the excavations in Fusṭāṭ (1960) carried out by the American Research Center in Egypt, under the Direction of Scanlon, bearing the Coptic inscription 'umila bi-Miṣr' (Goldstein,2005:134) dated to the period of the governor 'Abd as-Ṣamad ibn 'Alī (799 AD) (Kröger,1995:114;Shindo,2003:174,200). According to 'Abd al-Rawuf Yusuf, this leaves no doubt that Egypt was another centre of the production of lustre decorated glass (Kröger,1995:114;Shindo,2003:174;Carboni,2004:52;Goldstein,2005: 134).

The birthplace of lustre technique on glass was a much-debated subject because many scholars, such as Lamm, Dimand and Kūhnel, suggested that the technique was first developed by potters in Iran, Iraq and Egypt. In contrast, others such as Clairmont supported the idea that the technique may have developed in Egypt before the birth of Islam around the 4th century AD (Lamm,1941:30,18-19;Carboni,Whitehouse,2001:200;Carboni,2004:52;Goldstein,2006:134).

While the history of the technique is still yet to have been written, perhaps it is opportune to explore other avenues, such as the scientific analysis for the provenance of the spectacular piece of a lustre bowl from the Famen Temple in China, illustrating the superb quality that can be attained (Kröger,1995:115;An,1991:129;Carboni,2004:52;Shindo,2007:175;Jie,2010:186;Li *et al.* 2016:161). The bowl, dated before AD 874, was decorated with twelve black lustre irregular semi-circular elements and two lustre poppy or pomegranate flowers on a yellow background (An,1991:129;Shindo,2007:175;Jie,2010:186;Li *et al.*,2016:161). The bottom of the bowl was flat, and on the outside of the bottom, the pontil mark was visible (Jie,2010:186). The bowl was the only lustre glass that was found at the Famen Temple. In 2016, it was analysed together with seventeen early Islamic glass vessels by using a portable XRF spectrometer (Li *et al.*,2016). The analysis shows that the bowl was a plant-ash glass with a high concentration (higher than 1.5 wt%) of magnesium and potassium oxides. The bowl was plotted together with other lustre decorated vessels that had probably been made in more than one centre in Syria or Egypt but not in Iran/Iraq (Li *et al*,2016:175). Of course, such references do not offer definite clues as to whether Damascus in Syria might be the place of its production, but this research has alerted scholars to the exciting possibility of isolating Iran/Iraq as a place of production of the specific lustre bowl.

Among the considerable quantity of fine Islamic glass surviving today, glasses which have been signed from Damascus are not the only types of glassware that epigraphically indicate their provenance (Rice,1958:8;Carboni,2004:199). Four individual moulded glasses produced by the same craftsman, Ṭayyib ibn Aḥmad Barmasī[?], bear the Kufic inscription 'bi baghdā[d]' (in

Baghda[d]). These materials support the assumption that Baghdād was a centre of production of artistic glasswares during the early Islamic period (Rice,1958:8;Saitowitz,1996:39; Carboni,2004:199). In the centre of fertile plains and better irrigation, Baghdād grew rapidly, with the rise of the ´Abbāsid dynasty (AD 750-1258) and encouragement from the ´Abbāsid state. It became the centre of the Islamic empire and a centre of wealth and luxury (Hourani,1995: 64;Henderson,2013:254). From its foundation by al-Mansur in AD 762, the city, on the banks of the Tigris River, was designed to be the centre of the Islamic world. From their new capital, the ´Abbāsid caliphs and governors supported each aspect of art and hence the arts flourished (Whitcomb,2009:92;Henderson,2013:254). Moving the capital from Damascus to Baghdād, artisans and the paraphernalia of their entire workshops could have been moved with the caliph (Henderson,2013:254). Under such favourable circumstances where the arts were supported, the production of artistic wares from metal, glass and porcelain was prompted. Within the environment of the new capital, the traditional skills and crafts prospered. It is especially interesting that the artisans developed traditional decorative techniques, such as blowing glass into a patterned mould (this has already been exploited in workshops from the 2nd or the 1st century AD) and inscribing the vessels with blessings in Kufic script (Kröger,1995:85; Carboni,2001:197;Carboni,Whitehouse,2001:51;Blair,2016:12). Moulded inscribed vessels such as the above from Baghdād are characteristic examples of the new unique Islamic tradition that occurred.

Mould-blown decoration was a creative and exclusive technique in which the decorative patterns were countersunk on the interior surface of the glasses (Carboni,2001:198;Kröger,1995:85). Technologically, the technique consists of blowing a glass parison into a patterned mould (Carboni,2001:198;Kröger,1995:85). Thus, the first stage yields the impression of the external surface of the parison to the pattern of the mould (Carboni,2001:197). If the desire of the glassmaker was to produce shallower relief on the exterior surface of the vessel, they should subsequently reblow the parison (Carboni,2001:197). As soon as the desired surface was achieved, the glass parison was withdrawn from the mould to begin the process of tooling and twisting so as to achieve the desired decoration with applied trails (Kröger,1995:85). Two types of mould seem to be discernible in the development of the technique (Carboni,2001:198; Kröger,1995:85); the one-piece mould with a rich variety of glass objects, and the two-piece mould with conspicuous joints in which the vessel could be shaped in a mould with two or more parts (Kröger,1995:85). A minor problem arises when the decorative pattern consists of vertical lines at regular intervals, so it is difficult to say whether the vessel was created in one or more

mould pieces (Carboni,2001:198). But this was depended on the ability of the mould maker to conceive the decorative patterns in a clever way (Kröger,1995:85).

This is especially interesting because it highlights that the glassmakers of the moulded glasswares were linked with skilled craftsmen (possibly metalworkers or potters), who would have knowledge to cleverly create a clay, metal or bronze mould for glass (Carboni,2001:197). Apparently then, the glassmaker was not independent but worked in cooperation with the mould maker who was applying the values of fine art to the production of moulds for commercial glasswares (Carboni,2001:197). Whether the glassmaker was skilled in a wide range of arts and crafts, like many artists, and was the same person that could produce moulds under especially favourable circumstances, it is impossible to say. But it is important that in an environment such as in the new capital Baghdād, where quarters of workshops operated together, the glassblower and the neighbouring mould maker could cooperate (Carboni,2001:197). Hypothetically, the above craftsmen could form an alliance to maintain the ambitious standards of their workmanship either by discarding the mould to avoid further duplication or by protecting the secrets of their crafts to regulate trade and competition (Carboni,2001:197).

In the Medieval Arabic literature, stories of artists and craftsmen that kept their knowledge of the trade secret are known. Such is the story of al-Jāḥiẓ, about the 9th century AD miser, Khālid b. Yazīd of Baghdād, who promised before his death to reveal to his son the secret of how to manufacture glass by using a proper process of sublimation (Baker,2004:13). In the same century or no later than the 10th century AD, the workshop that was producing inscribed mould-blown pear-shaped miniature ewers was operating in Baghdād (Rice,1958:11;Carboni,2001:201). The selected ewers, which have been attributed to the Mesopotamia area and possibly to Baghdād, are either publicly owned and exhibited at institutions such as the Toledo Museum of Art (Ohio) and the Metropolitan Museum of Art (New York)or privately owned such as the ewer that belongs to Messrs A. Churchill, Ltd (London) or the ewer that belongs to Mr. Ernst Kofler of Lucerne and was exhibited at Zurich in 1956 (Rice,1958:11;Carboni,2001:201). The first specimen kept in the Toledo Museum of Art, when identified in 1953, stood quite alone and unique, but later proved to belong to the category of nine mould-blown pear-shaped miniature ewers with the same inscription, probably blown in the same or slightly different clay moulds (Rice,1958:11;Carboni,2001:201). Mention should be made also to the A. Churchill Ltd. Specimen, because it is the best-preserved example where the letters of the Kufic script stand out much more clearly.



Figure 2.4.1.2.: *Ewer with molded inscription (https://www.metmuseum.org/toah/works-of-art/x.21.191/).*

The exhibited at the Metropolitan Museum of Art pear-shaped ewer (***Figure 2.4.1.2***, https://www.metmuseum.org/toah/works-of-art/x.21.191/) with the flattened base and the applied L-shaped handle conceals an inscription in high relief, separated by two rows of relief dots that can be read as:

'Among that which was made for the amir in Baghda[d?]/The work of Ṭayyib ibn Aḥmad Barmasī[?]'(Carboni,2001:200).

In the upper line, the word Baghdā[d] occurs but the last dāl is missing. Attention must to be drawn to the name Baghdād instead of the name Madīnat as-Salām, chosen by Manṣūr for the new capital (Rice,1958:16). The rule to use the name Madīnat as-Salām on coins and ṭirāz bands need not have been applied on art objects made for private customers (Rice,1958:16). Nevertheless, for this thesis the use of the word Baghdā[d] is especially interesting because it confirms the literary evidence for the existence of a glass industry there (Rice,1958:16; Carboni,2001:200). The lower line of the ewer adds the master-signature (either the glassmaker or the maker of the mould) but this ewer is not useful when attempting to interpret the lower line. The most useful are the ewers in the Toledo and Corning collection, on which can be read

the name of the glassblower, Ṭayyib, without the article 'al' that was the rule for names such as al-H(ā)rūn, al- Q(ā)sim, etc. (Rice,1958:13). The absent article 'al' is confirmed by the ewer belonging to Kofler, on which can be read the lām before Ṭayyib (Rice,1958:15).

When turning to the word 'Baghdād' as evidence of an existing glass industry, it must be mentioned that there have been a few related moulded ewers, similar in shape and dimensions, found in the Mesopotamia area, such as the one from Kufa bearing an inscription with the name of the glassmaker 'Umar ibn Ibrāhīm', the other excavated in Iraq bearing plant motifs with birds and the third from Ghubayra in Iran with figural motifs (Carboni,2001:200). Given the trade that occurred, the above ewers could have been produced in Baghdād, but this requires further scientific investigation with trace element analysis. Trace element analysis has the potential to distinguish between glass found in the Mesopotamia area (Henderson *et al.*,2016:142). Recent trace element analysis conducted by Henderson and his colleagues shows that glass found at al-Madā'in (Ctesiphon) was possibly made in Baghdād and can be clearly separated from other glasses made 84 miles apart in Sāmarrā (Henderson *et al.*,2016:142).

2.4.2 Al-Raqqa

Baghdād and al-Raqqa, northern Syria stand out as a candidate for the production of the vessels bearing mold-blown decoration (Saitowitz,1996:39). It cannot yet be known whether al-Raqqa was the city where an atelier could use a technique, especially popular during the early Islamic period and already known from the Roman period, of decorated glass by incising its surface with a hard stone, probably diamond, point (Kröger,1995:116;Carboni,2001:71). But we are in a position to speculate on this question, because the Syrian city of al-Raqqa provides us with a richness of archaeological evidence (Tonghini,Henderson,1998:114;Henderson,1999:238). Al-Raqqa was a prosperous city and, for a short period (AD 796-808), it was the capital of the ''Abbāsid empire, extending across a massive geographic area from Spain to northern India (Wenzel,1986:222;Henderson,1999:238;Henderson,2003:109). The archaeological excavations undertaken since 1996 at the site show evidence of a full range of production processes, which led to the mass production of high quality glass during the 8th-9th, 11th and 12th centuries AD (Henderson,2003:110). When the caliph Hārūn al-Rashīd resided there with his armies and administrative structures, it seems that the demand for glass in the city increased dramatically

(Henderson,2003:109). Here, there was a craft specialisation into the selection of specific raw materials to make glass vessels, cast glass blocks and window glass (Henderson,1999:238; Henderson,2003:110). During the 8th century AD, three compositional types of plant-ash soda-lime-silica glass were in use for a short period (around 30 years) at the site of Tell Zujaj in al-Raqqa (Tonghini,Henderson,1998:114;Henderson,1999:223;Henderson,2003: 112). The most interesting fact is not that four compositional types (three plant-ash and one natron) were in use at the same time, but that three of the types (type 1, plant-ash glass, type 2, a mixture of natron and plant-ash glass, type 4, plant-ash glass) were primarily produced there in both single-chambered tank furnaces and three-chambered bee-hive furnaces, according to the structural evidence (Henderson,2003:112,114). All the compositional groups were used for the production of a range of vessels such as beakers, bowls, jugs, phials/flasks and undiagnostic vessels (Henderson,1999:234). Lastly, two of the compositional groups were manufactured to be used as window glass in the western and eastern palatial complexes.

As far as can be made out, the western palace must be dated to around AD 796-808, a period when Hārūn al-Rashīd built several palatial complexes (Henderson,2003:109). It is logical to assume that the caliph, like the previous Umayyad leadership, wanted to incorporate glass, either as window glass in the architecture or as artefacts in the decoration of the palaces, to convey to the observer a notion of prosperity, power and status of al-Raqqa, in a period when the city was meant to be the centre of a large empire (Henderson,1999:234;Baker,2004:4). Moreover, there is no doubt of Hārūn al-Rashīd's appreciation of glass, as the fabulous green glass drinking bowl in his treasure clearly shows (Baker,2004:7). The bowl is round like a human skull and was previously owned to by Umm Hakim, (AD 724- 43), a favourite of caliph Hisham. The bowl survived the fall of the Umayyad dynasty; it was obviously a luxurious object, with a gold handle weighing eighty mithqals (gold dinar coins), as recorded in Hārūn al-Rashīd's treasure (Baker, 2004:7). Apparently, the caliph wanted to incorporate activities, such as glassmaking and glassblowing, in his new society; an obvious sign for that was the 3 kms industrial complex with a full range of production processes involving firing technologies for the mass production of glass, glazed and unglazed pottery and a smaller scale of iron (Henderson,2003:109).

Here, it must be pointed out that in a highly developed and sophisticated environment in Tell Zujaj, the glassmaker and the glassblower could share knowledge of how to use the kilns and the firing temperatures with craftsmen that handle the same or similar non valuable materials. However, it is not surprising that in this place, there were unexpected discoveries; instead of the two known compositional types of Islamic translucent glass, four principal compositional types were found (Henderson,1999:238,Henderson,2003:109). It is furthermore possible that the

glassworkers knew the working properties of different colours of green glass and could choose their material only by their colour (Henderson,2003:120). Only in a city like al-Raqqa not based purely on agriculture and husbandry could the craft of glass be developed.

A technological change from the use of natron to the use of plant-ashes could have taken place 25 years earlier than AD 854, which is the presumed date for the change from natron to plant-ash as an alkali source (Henderson,1999:238;Henderson,2003:109). Technologically, successful experimentation with materials produced plant-ash glass of the type 4 (high aluminia) with very low silica levels and high magnesia levels, using new alkali-rich plant-ash from the halophytic plant (Henderson,1999:223;Henderson,2003:113). In Tell Zujaj, the discovery of a workshop and a frit with glassy phase of type 4 glass was extremely important in establishing that a workshop existed there responsible for the production of type 4 (plant-ash) glass and to link the composition type with Tell Zujaj in al-Raqqa (Henderson,1999:238;Henderson,2003:113). In fact, the workshop was responsible for the production of a range of compositions of glass type 4, as the differences in the magnesia levels show, using different plant species (probably of Salsola) to produce primary glass for making windows used on the construction of the western and eastern palace complex (Henderson,1999:238). The experimentation with different plant species in al-Raqqa is by no means an isolated phenomenon in the history of glassmaking in the early Islamic world. We come upon a similar experimentation in Beth She'arim intended to produce a different type of glass. It is worth hypothesising why that experimentation may have come about in the early Islamic world because the glassmaking centres probably desire an independence of supply of natron or of recycled glass (Henderson,2003:120). The conclusion seems inescapable: we have to assume, even without available evidence, that in the early Islamic period the dynastic rivalries led to the emergence of independent centres, as the establishment of new industrial complexes shows (Henderson,2003:120). Once this new dimension of experimentation has been recognised, the next important issue is the available evidence for the existence of a glass production workshop in Tell Zujaj (Henderson,2003:112).

Under such favourable circumstances, where three types of glass were fused using local raw materials, the existence of a workshop responsible for vessel production is not strange (Tonghini, Henderson,1998:114;Henderson,1999:238;Henderson,2003:112). From the three types of glass that were produced in Tell Zujaj, there can be little doubt that type 4 glass was used in the production of vessels. The discovery of the pontil ring found in the same industrial complex is noteworthy; the pontil ring shows evidence of the coexistence of primary and secondary glass production in Tell Zujaj (Tonghini,Henderson,1998:114;Henderson,1999:238;Henderson, 2003:112). Chemical analysis shows that the ring of the pontil was produced there using plant-

ash glass of type 4 (Henderson,1999:238). As far as can be made out, the above fact could indicate that the glass vessels of type 4 could also have been produced there (Henderson,1999: 223). But not only vessels of glass type 4 but a range of glass vessels could have blown in al-Raqqa using all four types (type 1, plant-ash glass, type 2, a mixture of natron and plant-ash glass, type 4, plant-ash glass)(Henderson,2003:112). Even the body of the thinly blown beaker with the applied blue trail around the rim and the two samples of a translucent blue glass horn with applied translucent brown decoration made of natron type 3 glass could have been blown there or could have been imported from the Levantine coastal production area, where trace element analysis proved that there was a specialisation on trail-decorated vessels (Henderson,2003:113, Henderson *et al.*,2016). But this is only speculation, because without the existence of pontil rings, moils or drops, we are not able to draw any conclusions with reasonable certainty, primarily due to the range of the vessel forms found in al-Raqqa which were common across a large geographic area during the early Islamic period (Henderson,2003:112).

Intriguing clues about the manufacturing of high quality, vividly coloured glass in al-Raqqa during the ´Abbāsid period led to the assumption that the high-quality artwork of plant-ash glass with the finely incised or scratch decoration could have been produced (Kröger,2005:142,Carboni, 2001:81,Henderson *et al.*,2016). This decoration had various degrees of sophistication, which was the most diagnostic of the period, and has been found in every major centre (Kröger,1995: 116,Carboni,2004:81,Kröger,2005:141). While searching for archaeological evidence, it is noteworthy that al-Raqqa is among al-Mīnā, Nessana (Auja al-Harif), Sāmarrā (Jawsaq al-Khaqani/Dar al-Khilafa palace), Nishapur, Susa, Fusṭāṭ, and Sīrāf, where fragments of incised decoration have been unearthed (Kröger,1995:116; Kröger,2005:141). In addition, complete or near complete vessels on the market have been promoted by dealers and collectors in the region of al-Raqqa and Larisa (Shayzar) (Carboni,2004:81).

2.4.3 Scratch decoration and al-Raqqa

It is nowadays theoretically and scientifically possible that, when al-Raqqa was the ´Abbāsid capital, a local glasshouse existed there, where craftsmen decorated the glass surface with a sharp, pencil-like instrument (probably a diamond point) by scratching linear, geometric and vegetal designs (***Figure2.4.3.1***,Walton,2012:84)(Kröger,1995:117;Carboni,2004:76;Kröger,2005:140;Li *et*



Figure 2.4.3.1: *Incised linear and foliation patterns Syria or Iraq (Walton,2012:84).*

al.,2016:115). The glass used was usually vividly coloured so that the scratches left a permanent whitish mark, but sometimes paler colours such as green, greenish, or aquamarine was used (Kröger,1995:117;Carboni,2004:76;Kröger,2005:142). Thanks to the results of chemical analyses of four shallow plates from the crypt of the Famen Temple in China it has been shown from the wide palette of vivid colours (dark blue, amber, greenish yellow, manganese purple) that in al-Raqqa the craftsman had a preference for a blue colour in various shades, from dark blue to blue during the 8th and the mid-9th century AD (Li *et al.*,2016:115).

For a number of years, the discovery of the blue plates decorated with branches and plant leaves and 14 Islamic glass items in the crypt of the Famen Temple have attracted wide attention (Li *et al.*,2016:157;Jie,2010:183). According to ancient documents, the early Islamic glass in the 'Underground Palace' in Famen Temple, which was sealed in AD 874, entered China from Syria, Mesopotamia and Iran through the Silk Road during the 4th to 8th century AD (Jie,2010:183). Recently, eighteen Islamic glass samples were analysed to pinpoint the place of their production (Li *et al.*,2016:158). Chemical analysis results shows that the glass samples, according to soda and lime oxide levels, were similar to Nishapur (Iran); but it was interesting that one of the scratch-decorated blue plates was made in Nishapur and surprisingly four were

probably made in Syria in terms of the relative MgO and CaO oxide levels (Li *et al.*,2016:175). Attention should be also drawn to the fact that the plates are similar to other scratch-decorated vessels that have been found in Syria (Li *et al.*,2016:175). More important is that there was an atelier in Syria that could produce the pedestal shallow plates with the use of geometrical ornament and naturalistic plant forms to a great degree of sophistication and elaboration (Kröger,1995:117;Li *et al.*,2016:175). Although the quality of the decoration varies, and its plate has its own characteristics, all the plates show fine hatching of the background to highlight a decorative element (Jie,2010:185). The decorative patterns were of varying degrees of complexity, arranged in bands, and featuring flowers, maple leaves, petal-like structures, lobes, four or five-petaled leaves, diaper, cable, and border patterns (Kröger,1995: 117;Kröger,2005:145; Jie,2010:185-186;Li *et al.*,2016:160-161). The execution of all the above decorative patterns on a glass surface that was so vulnerable and hard demanded skilled craftsmen, since they would need the utmost precision and precaution otherwise too much pressure could break the surface (Kröger,2005:140).

Stylistically, the decorative elements, such as the five-petaled leaf, the diaper, the cable and the border patterns, of the four scratched decorated plates were identical to two incised fragments of shallow plates unearthed during the excavations in Nishapur (Kröger,1995:117;Kröger,2005: 147). The decorative elements share similarities both with lustreware and lustre glasses. The similarity of the plates with lustreware, it is worth mentioning the relative similarity of the plant motifs and the bands of the scratched plates of the Famen Temple with the lustre-stain glass plate uncovered in the crypt. The lustre stain plate shows two pomegranate flowers framed by twelve irregular and semi-circular elements (Jie,2010:186). Chemical analysis shows a Syrian or Egyptian provenance of the lustre-stain plate (Li *et al.*, 2016:175). Lustre-stain glasses have been found during the excavations in Fūstāt, but it is noteworthy that important objects were also found in al-Raqqa (Shindo,2003:174).

In the ´Abbāsid palace at al-Raqqa, excavators found a lustre-stained glass dating back from the end of the 8th to the beginning of the 9th century AD, perhaps from the period of Hārūn al-Rashīd (Wenzel,1986:222;Shindo,2003:174). The squat beaker, now at Damascus, is of clear glass, lustre painted in gold and chestnut, and bears vertical inscription bands of Arabic letters with a word (running from the bottom up) that is supposed to be 'amal', which means 'manufactured by' in Arabic (Shindo,2003:174). It is decorated with yellow rosettes and rounded petals (Wenzel,1986:223;Wenzel,1986:222). Whether skilled artists were able to produce the elaborate and sophisticated scratched and stained decorated plates in ateliers in Syria, and perhaps at al-Raqqa, it is not possible to say with certainty, but it may be reasonable to think that

it could have been produced there. Ateliers in northern Syria, perhaps in al-Raqqa, may have locally produced scratch decorated vessels in imitation of popular types of decoration of pottery (Kröger,2005:147). According to Kröger, Robert Charleston noted the obvious parallels with the decoration of the incised fragments from Nishapur, such as the scalloped leaf and the check pattern, suggesting a link between the incised decoration and motifs with the Mesopotamian lustreware of the 9th century AD (Kröger,1995:117).

2.4.4 Sāmarrā

The art history perspectives pointed out Mesopotamia, especially Sāmarrā, as the place where workshops practised in scratch decoration (Kröger,1995:118;Carboni,2001:81). Why has Sāmarrā been suspected so far? The similarity between the decoration of scratch glass and lustre pottery from the excavations at Sāmarrā is by no means an isolated phenomenon and not the only reason that the city was a candidate. Be this as it may, an indication that the glasses could have been produced there was the very fact that in the ´Abbāsid capital of Sāmarrā, the largest assemblage (24 small fragments) of scratch decorated glass was unearthed during the excavations undertaken by Ernst Herzfeld in 1911-1913. The assemblage mentioned in the day-books was found in a palace in the Jawsaq al-Khaqani/Dar al-Khilafa (Kröger,2005:140).The fragments came from nine different vessels, probably dishes, cylindrical beakers, jars and flasks, bearing incised decoration in dark blue, light blue and manganese glass; the motifs correspond closely to the common vegetal patterns with foliate and angular motifs (Kröger,2005:141). An indication as to the period in which the fragments originate can be gathered from the study of Karl Johan Lamm (Kröger,2005:141). Lamm, who published the fragments in 1928, dated them to the same century as the samples from the Famen Temple; although until today it remains quite uncertain where the fragments were decorated, Lamm's proposal was that this type of decoration was made in Iraq and Egypt, and possibly Syria (Kröger,2005:141). An immediate archaeological concern was whether scratch decorated glass was made in one or more centres (Kröger,2005:142). The answer to the question came recently through chemical and trace element analysis. In 2016, Henderson and his colleagues, based on the ratio of MgO:CaO, proved an inland production of plant-ash scratch decorated vessels in Sāmarrā, Iraq and in Syria (possibly al-Raqqa) and Iran

(possibly Nishapur) (Kröger,2005:142). In contradistinction to the use of plant-ash glass, Kato and his colleagues (Kato *et al.*,2009) earlier showed that the Egyptian II natron glass was also used for scratched decorated vessels. The result seems inescapable: it must be assumed that the glass was made in several centres across the Middle East, but the various styles were a specialised product. We now come to what has long been suspected in the history of art but not proven scientifically before, that secondary glass workshops in Sāmarrā were involved in the production of coloured glass vessels decorated there with the graffito technique, using plant-ash glass that was being made locally (Henderson *et al.*,2016:139,142).

The analysed scratched decorated vessels are dated to a period when Sāmarrā was the capital of the ´Abbāsid caliphate (833-883) (Pinder- Wilson,1963:34,Klein *et al.*,2000:58). After the decline of al-Raqqa and the movement of Hārūn al-Rashīd back to Baghdad in AD 808, al-Mutasim built the new capital Sāmarrā on Tigris some 80 kilometres. north of Baghdad, in present day Iraq. Glass shards, both architectural and vessels, have been found in the 'audience hall' of the ´Abbāsid caliph, al-Mutasim (r. AD 833-42) and in the great palace in the northern part of Jawsaq al-Khaqānī (Lamm,1928:4;Baker,2004:6;Schibille,2018:15). In 2018, through high-resolution analysis of a comprehensive glass assemblage from Sāmarrā it has been shown that there was new advanced ´Abbāsid glass industry, as well as the import of specific glass objects for the thriving new capital city (***Figure 2.4.4.1,*** Schibille,2018:2). It is logical to assume that al-Mutasim wished to incorporate glass decoration within the walls of his palace using glass not only in plaster work, mosaics and windows, but also in wall-painting.

The city was a massive cosmopolitan settlement so there must have been a great demand for glass, as shown by the discovery of numerous window glasses, a distinctive glass floor 'tile' in the 'audience hall', and several pieces of small lozenges, circular and 'cartouche' millefiori tiles in the royal complex of Jawsaq al-Khaqānī (Lamm,1928:4;Klein *et al*,2000:59;Carboni,2001:29; Baker,2004:6;Henderson,2003:120). The surface of the millefiori glass was undamaged and more probably was not used on floors but on the wall panels (Baker,2004:6). Here, an important parallel may be pointed out. The glass floor 'tile' discovered in the 'audience hall' is similar to the transparent colourless glass, with a very slight green or turquoise tinge, found in the excavations in al-Raqqa (Baker,2004:6). The craft tradition of these objects, presumably made by pouring hot glass into an iron mould of small squares, as in the manufacture of a mosaic cube, was similar. This tradition was by no means restricted to Sāmarrā; it was more popular in Syria, where it is also attested much earlier. The coexistence of a similar tradition in Sāmarrā and al-

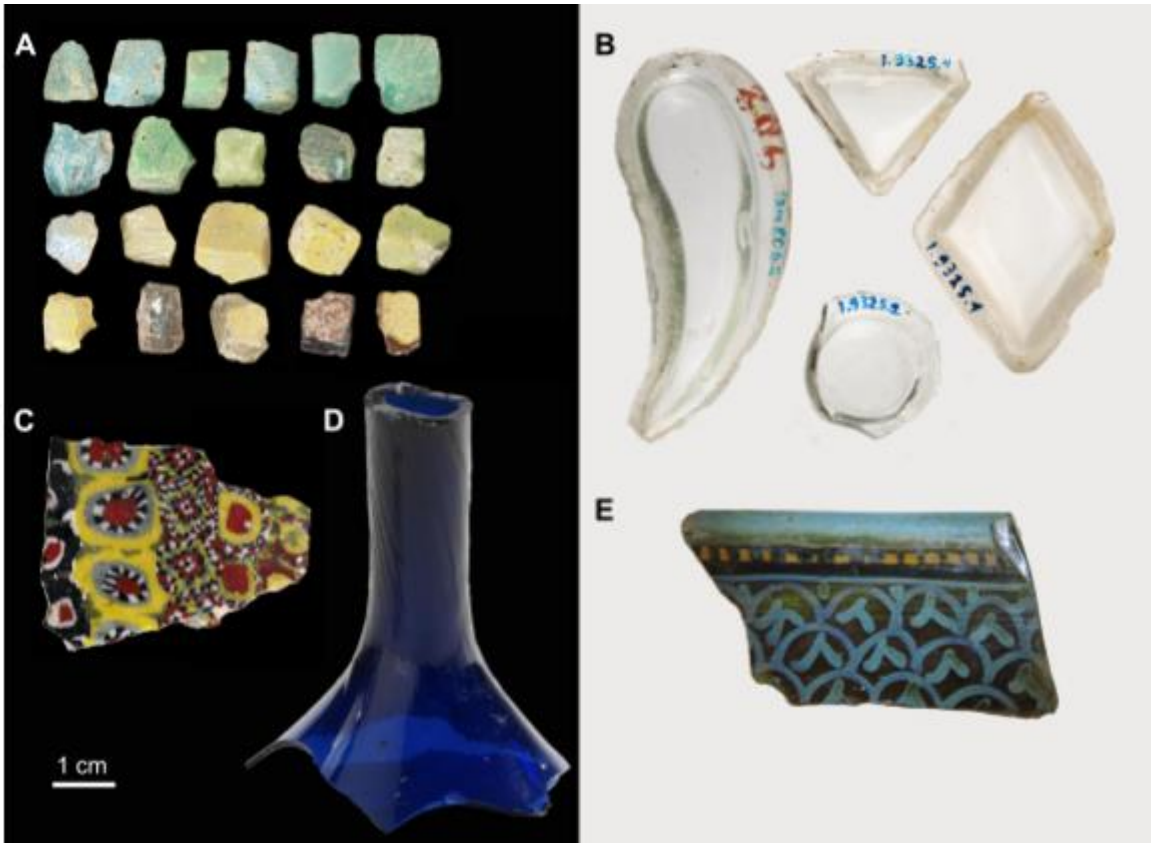


Figure 2.4.4.1 *Analysed glass artefacts from Sāmarrā (Schibille,2018:3).*

Raqqa is not a random phenomenon. This similarity between the sherds in the palaces and the execution from artisans that had this knowledge is an indication that glassworkers, along with the paraphernalia of the entire workshop, might have followed the Harun's departure and may have been encouraged to migrate to Sāmarrā (Ettinghausen,1942:6;Kröger,1995:115;Giralt,2014:13; Henderson,2003:120).

Before considering the results of the scientific analysis (chemical and isotopic) of the establishment of glass workshops in the new industrial complexes in Sāmarrā, it is important to examine the reasons why the capital Sāmarrā wanted to be an independent glassmaking centre (Henderson,2003:120;Schibille,2018:3). That Sāmarrā was an independent glassmaking centre has been proved through major, minor and trace element analyses of plant-ash glass that show that glass was made and used there, increasing our awareness and knowledge of glass production in the Islamic lands (Henderson,2003:120; Henderson *et al.*,2016:142). Furthermore, it has been established that there was separate glass production between Sāmarrā and other cities, such as Ctesiphon, even though at a close distance, which is only 84 miles away (Henderson *et al.*,2016: 142). The dynastic rivalries of the 9th century AD and the constantly shifting political allegiances

between Islamic groups led cities in the Iraqi lands (Sāmarrā and Ctesiphon) to be independent in their own supply of raw materials needed to produce glass. What is more, it seems that the glass workshops in Sāmarrā wanted to be independent by recycling and mixing different proportions of glasses (Henderson *et al.*,2016:141). Here in Sāmarrā, chemical analyses of a group of glasses with the highest and lowest 1000Zr/Ti values provide a possible indication of recycling and mixing of different proportions of glasses that were produced and used there (Henderson et al.,2016:141). One might easily think that if the capital wanted to be independent, it would demand the movement of artisans from distant corners of the caliphate bringing their own traditional ways of doing things (Henderson,2003:120); if artisans were moved from al-Raqqa, there would be continual experimentation with new alkali-rich raw materials so as to be less dependent on recycled glass (Henderson,2003:120).

Scholars have long been aware of the existence of a glassmaking and glassworking industry in Sāmarrā, although foundations of glass workshops (furnaces) or slag glass were not recorded during the German excavations (Lamm,1928:4;Henderson *et al.*,2016:139;142; Schibille,2018:15). In his book 'Das Glass Von Sāmarrā' (1928), Lamm wrote that although foundations of glass workshops were not found, it was firmly believed that Sāmarrā, alongside the neighbouring town of Tigris Ort Qādisīyah, was a glass manufacturing centre, at least for window glass, glass for wall decoration, for bottles and undecorated vessels (Lamm,1928:4). Furthermore, the author attempted to identify the place where furnaces of the glass workshops can probably be found; Lamm proposed the area east of 'Āshiq, on the Tigris, next to Kūrah and Kuwair, as a place where kilns can be found (Lamm,1928:4). In the area north of the investigated settlements, no ruins of palaces or private houses were found, although a number of glass objects were uncovered there, which suggests that this location was probably the area belonging to a glass workshop (Lamm,1928:4). It is tempting to suggest that the vessels and the architectural glass found in the southeastern corner in the northern part of Djausaq al- Khāqānī were products of that glass workshop (Lamm,1928:4). Chemical analysis has shown that high quality plant ash Mesopotamian architectural glass and all colourless glasses were produced in Sāmarrā. Furthermore, all the diamond shaped and round wall inlays, finely decorated vessels such as a cold-painted, gilded and engraved round bottle, and a relief cut bowl decorated with palmette and animal motifs were also produced in Sāmarrā. The cobalt blue flasks and some miscellaneous samples point likewise to an eastern Mediterranean provenance (Schibille,2018:7). The only products that cannot be considered as local production but as a

hoard were the 170 blue vials discovered in a room that adjoins the throne halls of Djausaq (Lamm,1928:4).

From the wide gamut of the characteristic decorations such as scratch, mould, pinched, lustre, cut or cameo decoration, practised in glass workshops in Sāmarrā, the cameo technique must be mentioned first (Lamm,1928:138;Henderson,2003:120;Henderson *et al.*,2009:424; Henderson *et al.*,2016:139). In cameo technique individual roundels of glass of different colors were gathered around a core (***Figure 2.4.4.2,***Carboni,2001:30;Walton,2012:80). Major, minor and trace element analyses conducted by Henderson et al. (Henderson *et al.*,2016:139) of five cameo decorated vessels housed in the Museum for Islamic Art in Berlin have proved that the above most fascinating type of Islamic overlaying and cut glass was produced in Sāmarrā's glass workshops during the 9th century AD using local blue, pale blue, emerald green and colourless glass. The first question that readily arose was whether the results of the analyses agree with the already existing archaeological and historical information. The available information was that the two-layered bi-coloured decoration was probably produced there because Sāmarrā was the only archaeological site where that decoration has been found (Carboni,2001:82). Through a process of absorption and transformation, it seems that the glass workshops in Sāmarrā had refined the previous Roman cameo technique (Klein *et al.*,2000;Carboni,2001:82); but they had developed a unique style of their own and gave birth to their own decorative artistic language (Kröger,1995:35;Carboni,2001:83). Here, the blue palmettes in the colourless pale blue body of the analysed bowl were in no way atypical but were characteristic of that new artistic language (Henderson *et al.*,2016:137). The Sāmarrā's artistic language featured plant designs, usually palmettes, that became more stylized, arranged symmetrically or in panels; those designs, although not naturalistic, became more formal and clearly distinctive from the established Iranian models (Carboni,2001:83). So scientific analysis has confirmed archaeological hypothesis.

The new artistic language of stylized palmette motifs developed in Sāmarrā's workshops is demonstrated in a range of techniques practised there, such as pinching and moulded decoration (Lamm,1928:136;Henderson *et al.*,2016:137). That consideration of the provenance of the glass was also proved by the above chemical analyses of a pinched decorated bowl and four pale green mould-decorated vessels, now in the Museum for Islamic Art in Berlin (Henderson *et al.*,2016: 139). The traditional mould decoration, in which vessels could be produced easily in massive quantities, must have been present in the capital (Henderson *et al.*,2016:139). The technique can be described as blowing a glass parison into a patterned mould and then removing it to be worked



Figure 2.4.4.2: *Shaped mosaic glass, Iraq (Walton,2012:80).*

again or to be shaped in two or more moulds; the prototypes of this technique were found in Sāmarrā's glass workshops from the previous Roman and Sasanian industries, facilitating a degree of continuity (Kröger,1995:85;Carboni,2001:197). There was a tendency to attribute cylindrical bottles with flat bases bearing decorations with complicated patterns to Sāmarrā; characteristic examples are the conventional geometric motif of intersecting lines that form a star at the bottom or the stylized image of an eagle with open wings (Carboni,2001:202/204). The eagle on the mould decoration may represent a stamp, characteristic of a Sāmarrā workshop (Carboni,2001:202). Finally, in contradistinction with the traditional moulded and cameo decorative techniques, a new decorative technique was also practiced in glass workshops in Sāmarrā; the new technique includes motifs that were impressed in relief and applied to the wall of the vessels, using pincers (Kröger,1995:95;Henderson *et al.*,2016:139).

In Sāmarrā's glass workshops during the 9th and 10th century AD, a particularly famous trend highly stylized design not only in mould-blown glass vessels but also in slant-cut pieces, although the motifs were abstract, and the patterns were deep outlined (*Figure 2.4.4.3,* Kröger,1995:163,Walton,2012:88). Relief-cut decoration, which is another important time-consuming technique possibly practised by glass cutters in Sāmarrā (Charleston,1942:215;Kröger,1995:120). There are no indications from the recent chemical analysis that Sāmarrā was a place that the technique was practised. Slant-cut or the so-called bevelled decoration was the most visually successful wheel-cut technique, characterised by the absence of a second plane, which would customarily supply the background; vessels decorated with that technique display hollow-cut lines, separating identical designs, and slanting cuts with a cross section like a check (Pinder-Wilson,1968:99;Kröger,1995:164;Carboni,2001:71). The main characteristic of the new style, known as Sāmarrā 'Style C', was the visual quality, symmetry, repetition, abstract themes, simple, elaborate or complex geometric patterns, strong sculptural vibrancy and decoration covering the whole surface (Kröger,1995:164;Carboni,2001:72). The decorative patterns were highly stylized and the vegetal, animal and geometric motifs, arranged horizontally or diagonally, were rendered with a single or a double outline (Kröger,1995:163). Major areas of the animals' or birds' bodies were crosshatched or hatched (Kröger,1995:165;Carboni,2001:72).

It is possible to ascertain information about the practice of the craft in Sāmarrā from a fragment carved with a fantastic animal bearing several features (nose, mouth, eyes, ears) detailed but clearly different from the well-known Iranian features on relief cut glass (Kröger,1995:142). Stylistically, a common feature of the Iranian glass was the dotting on the body of the fantastic animal (Kröger,1995:142). The craft tradition of the drilled dots on the body, the notched outlines, the not countersunk head, the striated neck and the countersunk body of which the Sāmarrā fragment derive was by no means restricted to Iraq (Kröger,1995:142). It was in fact more popular in Iran, where it was attested much earlier (Lukeins,1965:199;Kröger,1995:142). During the middle of the 9th century AD, relief cut glass have been found in Iran and Iraq that are decorated with exceptionally high quality carved animals such as a frieze of ibex-like animals or a frieze of unidentified animals.



Figure 2.4.4.3: *Deeply slant-cut planes on thickly rendered glass, Iraq (Walton,2012:88).*

An Islamic-style glass decoration with plant and animal motifs has been found in those regions, but without the presence of wasters or furnaces, it is difficult to prove that relief cut glass was made in the place it was found (Kröger,1995:35). For example, there has been a tendency to attribute much of the early Islamic glass to Gurgan, a city northeast of Tehran near the Caspian Sea, or to Nishapur, because of the quality found at these places which would seem to indicate important centers of the industry; this assumption is faulty. An excellent example of relief cut decoration, is the Buckley pear-shaped ewer, from an unknown and unidentifiable site in Iran now in the Victoria and Albert Museum, London (***Figure 2.4.4.4***, Lamm,1928:68;Kröger,1995:142;Contadini,1999:323;Carboni,Whitehouse,2001:185). The carefully worked ewer belongs to horn coloured engraved glass with a double outline of a bird, cross-hatching on its body and herringbone patterns in the panels (Charleston,1942:215). It is extremely important that the neck and shoulder of a bottle, of a very similar shape and decoration to the Buckley ewer, were found at Sāmarrā (Lamm,1928:68;Charleston,1942:215).



Figure 2.4.4.4: *The Buckley ewer now in the Victoria and Albert Museum.*
(http://collections.vam.ac.uk/item/O2360/the-buckley-ewer-ewer-unknown/)

There can be little doubt that the Buckley glass ewer and the fragment from Sāmarrā are an example of relief-cut resemble with the rock-crystal (Contadini,1999:323). The resemblance was noticed by Lamm and Charleston who wrote that this type of glass might have been used as an acceptable substitute for the precious rock-crystal (Kröger,1995:142). It is noteworthy that the shape and the decoration of the Buckley ewer is similar to the Fatimid rock crystals but the low foot, the handle and the analogies with the pear-shaped body are characteristic of Sasanian bronze objects (Contadini,1999:323). Nevertheless, it is risky and inappropriate to assign the Buckley ewer to Egypt rather than Iraq/Iran, since a glass ewer (now in the Corning Museum) with decoration practically identical to the Buckley ewer and the rock-crystal ewer of the Victoria and Albert Museum, was acquired in Iran and considered Iranian (Contadini,1999:323). There was a general tendency to impute colourless cut-glass vessels to Iraq and Iran, both important centres of the glass-cutting industry during the ´Abbāsid period (Charleston,1942:217). It seems that there already existed from the Sasanian period an established tradition of cutting colourless

glass vessels and there is no reason to think that this was interrupted after the 7th century AD (Lukeins,1965:202;Hayward,1977:120;Kröger,1995:123). The hemispherical and thick glass decorated with concave facets were characteristic of the cut glass (Harden *et al.*, 1968:98;Pinder-Wilson,1968:98;Klein,Lloyd,2000:58). The small hemispherical bowls were exported to the East and West, some even reaching Japan in the 6th and 8th centuries AD (Harden *et al.*,1968: 98;Pinder-Wilson,1968:98;Klein *et al.*,2000:58). Facets, either with shallow or deep cutting, could be found not only in shape of bowl but flaring, elongated, cylindrical or conical beakers, miniature jars, jugs, shallow dishes and bottles (Kröger,1995:123,Goldstein,2007:46); glasshouses could produce a variety of facet cut from round and oval (covering large surface areas) to square (covering the necks of the bottles) and parallelogram (Kröger,1995:123). Usually the glass was colourless (the standard colour for wheel-cut decoration) but nevertheless colourless glass with a light green tinge was also used (Klein *et al.*,2000:58,Henderson *et al.*,2016:136). In fact, raw green furnace glass produced in Levantine was exported to Ctesiphon and Sāmarrā to be used by glass cutters to decorate facet-cut vessels (Henderson,2016 36). The facet-cut glass from Sāmarrā had a low Li/K ratio distinguished from similar vessels from Ctesiphon (Henderson,2016:36).

2.4.5 Ctesiphon

Ctesiphon, in east-central Iraq, also known as al'Mada'in, located on the left (northeast) bank of the Tigris River, about 83 km from Sāmarrā and 32 km from Baghdād, was, before the advent of Arabs, the capital of the Sāsānian empire. The archaeological discoveries and publications show that wealth and patronage fostered the arts and crafts. As a result, factories that operated during the Sasanian period were revitalized by the Arabs rulers, such as the art of cutting glass (Von Saldern,1966:17;Simpson,2015:7). The very strong degree of continuity is evident in the facet-cut vessels excavated from the Sasanian and early Islamic layers (Goldstein,2007:46). Particularly, the excavated examples were deep hemispherical bowls, very popular during the Sasanian period and the not-so-popular shallow dishes (Goldstein,2007:48). Before trace element analyses, it was impossible to say with certainty, based primarily on the archaeological excavations, which facet-cut bowls were Sasanian or early Islamic; the compositional results of

major, minor and trace element analysis conducted by Henderson and his colleagues show that the Sasanian glasses had higher concentrations of Fe and Cr in comparison with the Islamic glasses of the 9th and 10th centuries AD (Henderson *et al.*,2016:138). Therefore, trace elements analysis offers a better interpretation of the archaeological evidence. When turning to the results, it is obvious that eight facet-cut (colourless and pale green) vessels, a bowl and an ovoid vessel unearthed at Ctesiphon had high Cr/La ratios belonging to the well-defined eastern group of Iraqi/Iranian glasses; but were clearly distinct from other glasses made in Levant and Egypt that had higher concentrations of Fe and from glasses in northern Syria, Iraq and Iran with lower concentrations of Fe (Henderson *et al.*,2016:138). Under such circumstances, one can think that workshops in Ctesiphon inherited the art and craft of wheel-cutting of colourless plant-ash vessels from the Sasanian tradition in the same area but probably used raw materials from different locations (Henderson *et al.*,2016:139). The above outline facet-cut decoration was destined to become widespread, as the various versions of disk patterns show (Kröger,1995:130). The various styles suggest the existence of several workshops across the Islamic empire.

2.4.6 Fusṭāṭ

In the earliest Islamic settlement at Fusṭaṭ, the archaeological evidence pointed out the existence of a variant of the so-called 'bevelled' style, imitating the standards set by Sāmarrā's caliphal ateliers and a glass cutting style (incised, relief-cut, facet-cut) from eastern provinces (Pinder-Wilson,1968:99;Kröger,1995:35). According to Kröger, the Egyptians acquired glass-cutting techniques during the 10th century AD and soon reached a high level of technical mastery; a characteristic example is the cameo relief carved bowl with a pair of ibex (Kröger,1995:35). Fusṭaṭ was among the major centres of caliphate power, outside Iran, where large ewers carved with relief linear or figural decoration dated to the 10th and 11th centuries AD have been found (O'hea,2001:134). It is noteworthy that the carving of glass probably flourished in Fusṭāṭ in the same period as the carving of hardstones (Kröger,1995:119). The industry of carved rock crystal in Egypt had already been established from AD 957 to 1036, when the ´Abbāsid governor was Aḥmad ibn Tūlūn (***Figure 2.4.6.1***, http://www.1001inventions.com/glass. This is shown by a



Figure 2.4.6.1: *Rock crystal ewer made for the Fatimid caliph al-Aziz. AD 975-976.*
(http://www.1001inventions.com/glass)

considerable number of rock crystal vessels (Kröger,1995:119). The tracing of philological evidence seems to confirm that information; a Persian traveler, who visited Cairo between 1046 and 1050 AD, witnessed rock crystal cutting (Kröger,1995:119). Very few singed crystal carving pieces (three fragments) bearing the names of Fatimid's caliphs or high-ranking officials in the Fatimid administrations have provided additional information about the practice of cutting techniques in the period of our interest in Egypt (Kröger,1995:120). During the excavation at Fusṭāṭ, a cut-glass ewer and a bowl were found dating to the 9th century AD bearing decoration similar to the Buckley ewer and the bowl in the Victoria and Albert Museum (Kubiak,Scanlon 1979:106); due to the similarity it was quite clear that they were produced in Iran (Kubiak,Scanlon,1979:106). Of particular interest was another facet-cut fragment found at

Fusṭāṭ, bearing the same peculiarity (disks are not worked in very high relief and a grid remains between them) with fragments from Sāmarrā and Nishapur (Kröger,1995:130). Carl Lamm dated the fragment to the Byzantine period but according to Jens Kröger, its pattern (disks not heavily cut, not very high relief and with a grid between them) classified it as early Islamic (Kröger,1995:130). Generally speaking, nothing is known about whether facet-cut, incised and relief cut decoration was practised in ateliers in Fusṭāṭ Without chemical analysis results, the archaeologists cannot establish firm conclusions. Certain suggestions about decorative techniques that were practised at Fusṭāṭ can be offered only for the chromatic surface technique of lustre painting(Ettinghausen,1942:4;Scanlon,1966:105;Kröger,1995:135;Carboni,2001:52;Giralt,2014 :12-13).

While the history of craftsmanship of lustre painting on glassware has yet to be written, a glance through the second half of the 8th century AD, more specifically, when governor of Egypt was ‘Abd al-Ṣamad b. ‘Ali for one month in AD 773, shows the possible existence of a glass workshop at Fusṭāṭ where the chromatic surface lustre technique, with patterns such as the rabbit, the bird, the classical ‘feel’ of the lobed leaves, scroll and roundel-rosette, was highly developed (Scanlon,1966:105; Kröger, 1995:114; Carboni,2001:52). This craftsmanship at Fusṭāṭ of a very high order was confirmed by the most important object in lustre painting on glass history: a goblet found in 1965 during the second season of excavations at the very bottom of a pit beside a glass weight with the name of ‘Abd al- Malik b. Marwan, the last Ummayad governor of Egypt (AD 749-750) (***Figure, 2.4.6.2,*** Scanlon,1966:105;Wenzel,1986:216). The goblet, which has a 9.5 cm body and a rim diameter of 13.5 cm, bears on the exterior the following Kufic inscription:

‘Bismillāh al-raḥmān [al-raḥim mimmā ama] ra ‘Abd al-Ṣamad b. ‘Ali aṣlaḥahu Allāh wa ‘azza naṣruhu’

‘In the name of God the Merciful, the Compassionate. One of the things ordered by Abd al-Ṣamad b. ‘Alī may God make him prosper and his victory be glorified’ (Scalnon, 1966: 7, 1968: 195; Pinder-Wilson and Scalnon, 1973: 28-29). The excavations in 1972 verified the precise date of the goblet with the discovery of a splendid lustre glass which was found in an earlier phase of a building, together with coins of ‘Abd al-Malik b. Yazid (AD 750-8) and Muhammed b. Sa’īd (AD 769-74) (Kubiak,Scanlon,1979:114). The goblet found in 1965 bears sophisticated double-sided painting with the switching of bands lustred internally and externally, providing an



Figure 2.4.6.2: *Lustre painted goblet, Cairo, Museum of Islamic Art, Egypt (Scanlon, 1966: 105, Wenzel, 1986: 216).*

illusionistic effect (Scanlon,1966:105). This artistically and technically ambitious type of glasswork bears an inscription band at the rim painted on the outside, then a band of stylized leaves projecting from a continuous looping vine painted on the inside, then a wide frieze of nine stylized lobed-leaves and scrolls lustred on the outside and finally a roundel-rosette painted on the inside at the base (Scanlon,1966:105;Wenzel,1986:217). Judging from its decoration, it is obviously an outstanding effort on the part of the craftsman both to obtain the subtle effect of shading to give the impression of depth and to preserve the illusionistic late Roman qualities on glass painting (Wenzel,1986:218;Carboni,2001:52).

The habit of painting on both the inside and outside of glass vessels is also exemplified in another fragment found at the excavations at Fusṭāṭ with large bright orange vegetal scroll leaves against a pale green dotted background painted on deep blue glass (Carboni,2001:60). Another fragment, possibly once belonging to the same vessel and now in the Kofler collection, has the same vegetal scroll freely drawn in a way so as to create an effect of movement (Carboni,2001: 60). One of the most interesting effects of lustre painting is the three-dimensional aspect. Twenty-seven fragments of a painted lustre bowl were unearthed at the excavations at Fusṭāṭ directed by G.T. Scanlon (now in the Ashmolean Museum, Oxford), bearing the decoration of plant stems lustred on the outside and the leaves painted on the insides both with the rabbit and the bird

having highlights. When viewed with light behind it, this gives an impression of depth is given (Wenzel,1986:216). Its inscription is interesting, because the characters resemble the goblet found in 1965 (Wenzel,1986:216). The similarity might indicate that both were products of glass workshops existing in Fusṭāṭ but from a different period (Wenzel,1986:216). The hemispherical bowl of about 11 cm in diameter in all probability was better dated to the Umayyad rather than the ‘´Abbāsid period. Its decorative style, with a bird and a rabbit or hare separated by plants with spindly branches and bulb-shaped leaves, has parallels to the domestic decoration of walls and floors of the Umayyad palaces in Syria (Wenzel,1986:216). More specifically, its decoration does not resemble the ´Abbāsid stylized designs but is similar to the naturalistic designs of the gazelles, under a large tree, being attacked by a lion while nibbling leaves, known from the mosaic floor in the palace of Khirbat al-Mafjar dated from AD 743 to 744 (Wenzel,1986:216). According to Marian Wenzel, the taste for naturalism declined under the ‘´Abbāsid s and was replaced by a much greater stylization (Wenzel,1986:218).

2.4.7 Trade with the East

The most spectacular example of the stylization in painted lustre glass vessels is a stained glass plate from the crypt or ‘Underground Palace’ in Famen Temple, which can be dated to before 874 AD (An,1991:129;Kröger,1995:115;Carboni,2001:52;Shindo,2003:177;Jiang,2010:186;Li *et al.*,2016:161). The plate, which is 2.7 cm high and 14 cm wide at the diameter, was framed by twelve black, irregular, semi-circular elements on a yellow background and in the interior part was bearing two pomegranate flowers (Jiang,2010:186;Li *et al.*,2016:161). The stylistic analysis of the Famen temple plate has yielded perspectives open for further investigations. The designs applied in black pigment in a thickly orange painted surface and its characteristic rim (folded outward) have parallels to seven pieces of monochrome-type bowls found during the excavations directed by Mutsuo Kawatoko conducted in Raya in 1997 (Shindo,2003:174). Perspectives that has not suspected so far were open. Raya was a port city and active for the trade between the early Islamic empire and South-east Asia and China (Shindo,2003:177); so, the reasonable thought was that the Famen Temple stained glass plate had been brought from Syria or Egypt to Raya on purpose to be loaded on a ship (Shindo,2003:174). Recently, chemical analysis conducted by Li and her colleagues proved scientifically the Syrian or Egyptian origin of the

Famen Temple plate (Li *et al.*,2016:161). The analysis shows that the most superb quality of the plate belongs to a group of plant-ash glasses, with relatively high levels of Fe_2O_3 and MnO, de-colourised by a technique used in Roman times around the Mediterranean (by changing Fe3+ to Fe 2+) and was produced probably in Syria or Egypt (Li *et al.*,2016:161). But whether Fusṭāṭ was its place of production needed further investigation with trace element analysis (Li *et al.*,2016:161). We can now turn to another equally important result of the analysis conducted by Li and her colleagues from the Famen Temple treasure, that of the pinched decorated beaker with the vertical Kufic inscription (Li *et al.*,2016:161). The beaker was made of colourless glass, formed by blowing, and was decorated with repeated lozenge patterns, with rhombus and double circle patterns (Kröger,1995:95; Jie,2010:184;Li *et al.*,2016:161). Stylistically, Jie suggests that the place of origin of the beaker decorated by pinching may have been Nishapur. However, recent chemical analysis has shown that the beaker belongs to the same group as the lustre painted plate and the workshop may not located in Nishapur, probably in Egypt or Syria instead (Jie, 2010:184; Li *et al.*,2016:161).

Searching the location where early Islamic glasshouses practised the pinched decoration, it is essential to point out that chemical analysis seems to agree with the meagre archaeological evidence that point to Egypt (Fusṭāṭ) and Syria (al-Raqqa) (Wenzel,1986:222). The archaeological evidence is provided by a straight-sided beaker of turquoise glass (now in the Ashmolean Museum), excavated at Fusṭāṭ, with Kufic inscription pinched vertically, the glassworker has turned the glass on its side to execute decoration (a horizontal inscription would be much more difficult) (Wenzel,1986:222). It is noteworthy that the beaker has parallels to a squat beaker from Fusṭāṭ (now in Cairo Museum) that was described by Carl Lamm, and to a squat beaker of clear glass (lustre painted in gold and chestnut) excavated in al-Raqqa (now in Damascus) with a vertical Kufic inscription (Wenzel,1986:222). A pinched decorated fragment dated to 850-1000 AD was also excavated at the Nubian site of Qaṣr Ibrīm and other fragments have been found in Israel, Iraq and Iran (Wenzel,1986:226;Kröger,1995:95). Even though there is not enough archaeological information to form an idea about the origin of the technique, Lamm and Harden were of the opinion that pincered decoration on glass, such as the lustre painting of glasswares, seems to have originated in Egypt, at the time that Hārūn al-Rashīd achieved popularity in al-Raqqa and then spread to Iran and Iraq during the 9th century AD (Wenzel,1986:226;Kröger,1995:95).

2.4.8 Levant

In the Levant one or more workshops existed specialising in the hot-working technique of impressing the hot surface of the vessel using a pair of tongs; usually the tongs had identical patterns in relief on both jaws, as the repeated impressions in the same places on the inside and outside of the vessel show (Kröger,1995:95). Glassworkers preferred to decorate with this technique mainly open vessels as cylindrical beakers, plates and ewers, but could also decorate closed forms before the body was tooled and closed (Kröger,1995: 95,Goldstein,2005:15). The pinched decoration was characterized by great stylization with repetition of motifs (vertical lines, half cycles, concentric circles, concentric squares, V-shaped motifs, stylized palmettes etc) and the surface of the vessels were divided into panels by dots or dashes (Kröger,1995:95).

The Levant was also known for the habit of practicing another hot-working technique, that of using decorative trails or pads of glass applied to the hot surface of the vessel (Goldstein,2007: 15;Henderson *et al.*,2016:142). By using trace element analysis, characteristic pale green or pale blue plant-ash glasses decorated with pale green, cobalt blue or turquoise colours threads excavated at Nishapur, hypotheses can be made that specific workshops in Levant specialised in the applied decoration (Henderson *et al.*,2016:142). It was characteristic of the technique to apply decorative trails or disks of the same or contrasting colour as the vessel to the still-hot surface of glass (Kröger,1995:104;Carboni,2001:163;Goldstein,2007:13). It seems that ateliers in Levant were using pale green plant-ash threads on a pale green surface but when they desired to enhance the overall decorative effect, they applied cobalt blue or turquoise plant-ash threads on the pale blue surface of the plant-ash vessels (***Figure 2.4.8.1,***Henderson *et a*l.,2016:142). Strips were made to adhere to a vessel horizontally D or vertically (this decorative theme was known from Roman and Sasanian glassmakers), or in snaky, wavy or zig-zag designs (Kröger,1995:104;Carboni,2001:163;Goldstein,2007:13).

Attention has to be drawn to a place in Israel, further south from Beirut and Damascus in Levant. The trace element analysis outlined above revealed the existence of an atelier, where trailed decoration was probably practiced between the 8th and 10th centuries AD (Henderson *et al.*,2016:142). The important palatial site of Khirbat al-Minya has yielded a compositional well-

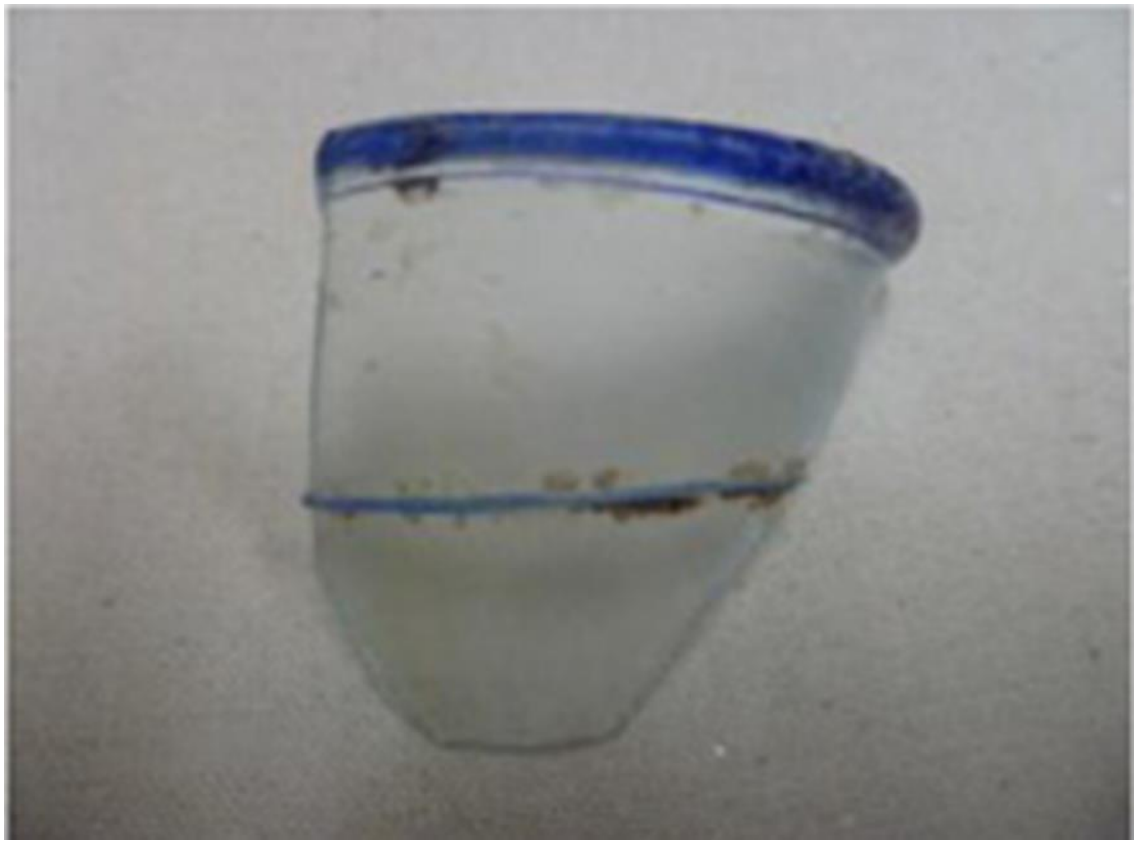


Figure 2.4.8.1: *Trailed decorated rim fragment from Nishapur but product of a Levantine workshop (Henderson et al.,2016:137).*

defined group of vessels (now housed in the Museum for Islamic Art in Berlin); among them, there was

a flask neck decorated with white trails on a purple surface (Henderson *et al.*,2016:137). As to the other vessels, these included a green flask with a pushed in base, a green flask tapering with a flat base, a green flask neck with handle, and a green flask with a straight neck and a brown window (Henderson *et al.*,2016:137). Trace element analysis was especially important because it shows that the vessels were well distinguished from other Levantine (Beirut and Damascus) glasses that have the lowest Cs/K ratios and from glasses (mosque lamps) presumably made in Cairo having the highest Cs/K ratios (Henderson *et al.*,2016:140). Mainly because the group falls geographically between Levant and Cairo, the assumption was that a glass workshop existed in an urban site close to Khirbat al-Minya, such as Amman or Jerusalem (Henderson *et al.*,2016: 142). When turning to the general results of the trace element analysis conducted by Henderson *et al.*, it is obvious that a centralised production model both for natron and plant-ash glass that was exported to sub-zones for the manufacture of a range of vessels existed (Henderson *et al.*, 2016:142). This rather strange model of sub-zones in the Levantine plant-ash glasses happens to

be offered by the well distinguished chemical composition of Beirut glasses with higher Cr/La and lower 1000Zr/Ti ratios from Damascus glasses (Henderson *et al.*,2016:139).

Chemical, isotopic and trace element analysis of plant-ash glasses dated to the first millennium AD suggest a link between chemical composition, vessel types, decorations and the place of manufacture (Henderson *et al.*,2016:142). But this was not the case for natron glasses, because chemical and isotopic analyses suggest two principal production zones for the raw material (in Egypt and in Levantine coast) but there is nothing noteworthy about the compositional relation between raw materials, finished products and the decorations (Freestone et al.,2008:80; Freestone *et al.*,2015:48;Henderson *et al.*,2016:142). This problematic situation is caused by the absence of diagnostic artefacts found during the excavations of workshops; studying the glass itself did not reveal insights into the processes of the decorations (Freestone *et al.*,2015:45). Trace element analysis is still needed of early Islamic diagnostic vessel types, both natron and plant-ash types, for a deeper understanding of glass workshop activity in the Islamic lands (Freestone *et al.*, 2008:80;Freestone *et al.*,2015:48;Henderson *et al.*,2016:142). For example, the analysis of twenty-four vessels, chunks and moils from an early Islamic workshop at Khirbet al-Ḥadra, Tel-Aviv (Israel), by Freestone et al. (Freestone *et al.*,2015:49), has shown that two types of glass, the Levantine and the Egyptian II, were used to produce the vessels. But the exact location of the workshop was unknown due to the absence of diagnostic types.

It was only established that the coexistence of two types at the same workshop was probably because of the different properties and the cost (Levantine glass was probably cheaper because of its inferior quality and needed more fuel and time to melt, making it harder to work; Egypt II had better properties and was probably preferred by the glassworkers but also more expensive) (Freestone *et al.*,2015:49). Furthermore, since the origins of the raw materials were estimated, it was also pointed out that products of the same workshop were bowls and bottles of colourless and bluish-green or yellow or yellow-brown tinge jars, beakers, cup-shaped lamps and 'wine-glasses' (Freestone *et al.*,2015:49). The only indication of the practice of a specific technique at the workshop was indirect, coming from a limestone mould (***Figure 2.4.8.2***, Freestone *et al.*,2015: 48). The assumption was that the mould was used by the glassworkers at the site to produce ribbed vessels (Freestone *et al.*,2015:48). However, ribbed vessels were not found at the site. Parallels can be found in a terra-cotta mould with molten glass inside uncovered in and around the remains of a glass workshop in Bet She'arim during the 1940s excavations (Gorin-Rosen, 2000:58). But establishing the decorative techniques used was not possible.

The same phenomenon was observed in Bet She'an (Scythopolis), where a glass workshop responsible for the production of specific forms of natron glass vessels has been discovered

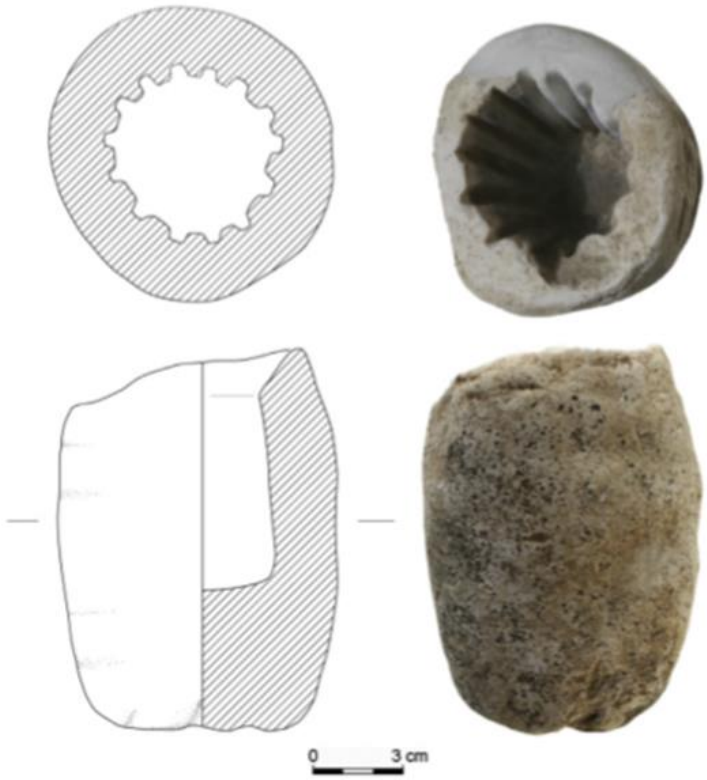


Figure 2.4.8.2: *A limestone mould for the production of ribbed vessels unearthed in Khirbet al-Ḥadra, Tel-Aviv (Israel) (Freestone et al.,2015:48).*

(Gorin-Rosen,2000:59). The excavations show that the workshop produced chiefly everyday glassware of small variety forms, such as bowl-shaped oil lamps (with hollow or solid conical stems or beaded stems), bottles (with globular, piriform or barrel-shaped bodies, with short cylindrical necks and funnel-shaped mouths, neckless), and wine-glasses with feet and base rings (Gorin-Rosen,2000:60). A similar case in Apollonia-Arsuf, where crafted vessels were produced by using local natron glass (the product of a primary workshop discovered there), provide an indirect indication of the existence of a glass workshop (Freestone *et al.*,2008:79). Meagre evidence of the existence of a workshop in Apollonia-Arsuf come from Ramla. This workshop was responsible for the production of everyday colourless tableware with a bluish tinge, such as bowls, lamps and wineglasses (Tal *et al.*,2008:87). In nearly all these instances, it cannot be said with certainty how closely related these workshops were with the vessel types, forms and decorations.

2.4.9 Nishapur

The existence of an atelier in Nishapur has recently been shown through chemical and trace element analyses (Henderson *et al.*,2016:139). This established that specific decorative cold-techniques in Nishapur were practised by glassworkers (Henderson *et al.*,2016:139). Chemical analysis result agrees with the proposals of the curator of the excavations and the scholar Kröger, who studied the glass from Nishapur. More specifically, in his book 'Nishapur: Glass from the early Islamic period' Kröger hypothesised that Nishapur in north-eastern Iran was an important centre for the manufacture of high quality glass during the 9th and 10th century AD (Kröger,1995:37). For a long time, Kröger's hypotheses for an outstanding production of glassware in Nishapur was based only on the high quality of rich glass finds unearthed there during the two seasons of excavations in 1942 (Kröger,1995:33). The remains of secondary glass workshops, including traces of furnaces, chunks of cullet or raw glass for melting, have not been uncovered at Nishapur, in contrast with the remains of a lot of pottery kilns found in the city (Kröger,1995:20). At Qanāt Tepe mound, only two glass slabs among glazed earthenware, spurs, and kilns debris were found but Wilkinson notes that the slabs probably came from a later date and were materials used in glazed pottery workshops (Kröger,1995:20). Unfortunately, the archaeological evidence was not enough to prove that the glass was produced near those pottery kilns. There is a possibility that the furnaces were situated outside the city walls and have not yet been discovered (Kröger,1995:20). The excavations at Sīrjān revealed seventeen glass furnaces, a fact that allows us to think that primary and secondary glass workshops must have existed in Nishapur (Kröger,1995:20).

There was a time when Iraq was thought to have held the monopoly of almost any splendid wheel cut vessel (Charleston,1942:217). In recent years, however, chemical and trace element analyses evidence have proven the existence of atelier/s in Nishapur, where glassworkers practiced the so-called scratch and facet-cut decoration (Li *et al.*,2016:175;Henderson *et al.*,2016:139). This result confirms, notwithstanding the references in the literary sources, that the principal city Nishapur was, along with Afrasiab, the production centre for the fine wheel cut glassware during the indigenous Samanid dynasty (819-1004 AD) (Pinder-Wilson,1963:38;Pinder-Wilson,1968:99;Fukai,1977:62;Kröger,1995:37). It has to be admitted that this evidence agrees with Kröger's original thought that there were no technical or artistic traits on the more

sophisticated wheel-cut and incised glassware, that would suggest that they were not local products of the workshop that existed in Nishapur (Kröger,1995:33). Especially noteworthy was Kröger's opinion that all the wheel-cut vessels came from a specific workshop because of similarities among the shapes (Kröger,1995:21). The Sasanian tradition of facets carved on a colourless body seems to have been revived in Nishapur during the 9th and 10th century AD (Henderson *et al.*,2016:139). In 2016, Henderson and his colleagues, using trace element analysis, detected evidence for a technological specialisation within the broad eastern zone in the production of facetted cut vessels, colourless in Nishapur and pale green in Ctesiphon (Henderson *et al.*,2016:139).

The importance of Nishapur in the production of colourless facet-cut vessels has been proved through the analyses of beakers, now in the Museum for Islamic Art in Berlin, cut decorated with circles, circles and lines, vertical lines or chevrons (Henderson *et al.*,2016:136). The relatively impure levels of Cr, Fe, La, Zr and Ti, mainly found in sand, identified that colourless cut and engraved (along with pinch decorated) glass dated to the 9th and 10th century AD found in Nishapur was made in the eastern zone in Iran and Iraq, clearly influenced by a Sasanian tradition but clearly distinguished analytically from the Sasanian colourless cut glass (Henderson *et al.,*2016:142). The object described above, made with sand containing low iron levels, has higher Li/K ratios than Levantine glasses and lower Cs/K ratios, and was distinguished from the Iraqi glasses from Sāmarrā having lower Cr/La ratios (Henderson *et al.*,2016:139). Be this as it may, now there is evidence that points to the solution of the problem of colourless facet cut glass from the Sasanian and early Islamic period as their distinction is somewhat baffling. Excluding facet cutting, the incised decorative technique was especially fashionable in Nishapur, possibly stimulated by the demands of the foreign ruler for luxury glasses as shown in the results of recent chemical analysis of intact shallow plates found in the crypt of a stupa Famen Temple (Famensi) in Shaanxi Province (Fukai,1977:62;Li *et al.*,2016:174). The plates found in China were very important for dating the glass with incised decoration before AD 874 (Kröger,1995:116-117;Carboni,2001:80). All the plates carry decorative elements (diaper, cable, border patterns) identical with two plates from Nishapur and five-petaled leaf (Kröger,1995:117).

The two shallow plates with finely incised decoration uncovered at the excavations at Nishapur were a fragment of dark blue glass and a fragment of yellowish green-tinged glass, both elaborately decorated with hatched motifs; the background was hatched so the motifs could stand out (Kröger,1995:116). The decoration was characterised by an unrivalled degree of sophistication and elaboration (Kröger,1995:116). The similarities of the plates in design, shape, and execution led to the conclusion that they were products of the same workshop; but whether that workshop

existed in Nishapur was difficult to say (Kröger,1995:116). Robert Charleston was of the opinion that the technique was maybe practiced in the same place as the lustre technique because of the similarities with the Mesopotamian motifs on lustreware of the 9th century AD. This means that there was no possibility of the existence of a workshop in Nishapur, but somewhere in Iraq, possibly in Baghdād or Baṣra (Brill,1970:354). But Kröger was of the opinion that there is no obvious reason the craft of incised decoration could not have been practiced in a workshop in Nishapur by skilled craftsmen (Kröger,1995:117).

The scientific research on vividly coloured glass with incised decoration does not offer any indication of the geographical area of the workshop. Though the evidence was meagre and difficult to evaluate, the historian of early medieval glass, Carl Lamm, made an attempt to identify the specific place and mentioned Syria and Egypt as places of production (Lamm,1928:79). In Syria, Larisa and al-Raqqa were the most likely candidates as a number of incised decorated glasses come from their art market (Carboni,2001:80). The very fact that Syria was a place where an atelier must have existed is proven by recent chemical analysis of four scratched decorated vessels from the crypt of the Famen Temple conducted by Li and her colleagues (Li *et al.*,2016: 174). According to the chemical analysis results, in terms of the relative MgO and CaO levels, four scratch decorated plant-ash (with higher MgO and K_2O than 1.5%) plates, according to MgO and CaO levels, may have been made in Syria and one in Nishapur (Li *et al.*,2016:175).

In addition, a lustre plate decorated with pomegranate flowers unearthed in the Famen Temple has been plotted in terms of its MgO vs CaO and compared with glasses from other places in the Islamic world and with lustre painted glasses dated to the 9th and 10th century AD unearthed in Raya, Sinai Peninsula (Egypt) (Li *et al.*,2016:175). The rim shaped plate, which is characteristically folded outward, has parallels with seven monochrome type pieces uncovered in Raya (Shindo,2003:175). The background colour of the bluish-green material is yellow and the decorative pattern black (Jiang,2010:186;Li *et al.*,2016:161). Similar examples of black pigment on orange lustre, extensively or fully painted on the inside or outside of the surface, but with more exquisite patterns, are thought to have been produced in Iraq. They are similar to the polychrome lustre pottery of the 9th and 10th century AD (Ettinghausen,1984:853;Rice,1958:9). Those fragments show very close connections with the lustre pottery, in its technique and artistic intent, representing an outstanding effort and a brilliant achievement of the potters (Ettinghausen,1942:6). An example of the same type of glass is in the Islamic Museum of Art in Cairo and another one in the Princeton Museum of Historic Art (Ettinghausen,1942:7). The importance of the fragments is the close parallels, in technique and ornamentation, with lustre pottery and the Kufic inscription bearing the word (a)l-Baṣrī (the man from Baṣra), which shows

the connection of the fragments with the town of Baṣra (Ettinghausen,1942:6-7). The Princeton and Cairo fragments identify the styles and techniques of the products of Baṣra (Ettinghausen,1942:7;Rice,1958:8).

2.4.10 Baṣra and Sīrāf

The port on the Shatt al Arab Baṣra in Southern Iraq was an important and well-known manufacturing place of lustre-painting on pottery, according to the recent scientific analysis of the clay used to make the ceramics (Ettinghausen,1942:7;Mason,Brill,1970:354;Keall,1991,Hallet, 1999:79;Giralt,2014:13). Situated sixty miles away from the Persian Gulf, in an ideal topographical area with roads across leading to Syria and the Nejd in the West and Iran in the east, the town developed into a great emporium (Ettinghausen,1942:6). Richard Ettinghausen, who studied the Princeton and Cairo fragments, identified the styles of the glass products of Baṣra, referring to a literary source and judging from the small-patterned style, suggests lustre pottery and glass might possibly have been made in Baṣra in the early and the most important period of Islam (Ettinghausen,1942:7). The most ambitious type of glasswork, the Cairo rim of a bowl made of blue glass, was coloured orange on the outside with a greenish reflection (bearing an orange Kufic inscription on a black background) and shows careless drawn scrolls and dots (Ettinghausen,1942:3). Several decades later, the Princeton fragment of greenish blue glass was painted with a dark reddish brown lustre-like paint but was made uses using a different technique and bearing a geometric design and a stylized palmette (Ettinghausen,1942:6/7).

The Princeton fragment is supposed to have come from the Fustāt, but its fragmentary inscription is more likely to be the signature of an artist coming from the town of Baṣra (Ettinghausen,1942:7); if Richard Ettinghausen's assumption is right, there is a possibility that the Princeton fragment and the Cairo fragment were made by a workman brought from Baṣra (Ettinghausen,1942:7). Stylistically speaking, the Cairo fragment has parallels with fragments found in the caliph's palace in Sāmarrā, probably made there in the temporary capital, prompting the assumption that workmen from Baṣra might have produced or reproduced lustre ware outside their home town of Baṣra (Ettinghausen,1942:7). This suggestion corroborates the information given by the historian and geographer Ya'qubi (ca. 891 A.) that glassworkers and

potters were brought from Baṣra to Sāmarrā (Ettinghausen,1942:4). The latter history of glass in Baṣra is until today not well-known. Little is known of the history of glass, closely related to the town, because the excavations concentrated on the site of the Great Mosque in Old Başra (which lies 16km to the west of the modern city) and these excavations were limited (Iraq,1973: 191). Scientific analyses have yielded hardly anything of importance in answer to the question of the existence of workshops in Baṣra. Nevertheless, Baṣra is considered a candidate for the 'Iraqi' glasses uncovered in Unguja Ukuu (Africa).

Sīrāf, located in a strategic position on the north-eastern coast of the Persian Gulf, must have been a place where a glass workshop during the 9th and 10th century AD produced vessels using local glass, according to the view of David Whitehouse (director of the seven seasons of excavations at Sīrāf) (Whitehouse,1968:22). The 1966 excavations at Sīrāf have uncovered an industrial complex which manufactured pottery and possibly glass, in a suburb near the western edge of Sīrāf (Whitehouse,1968:22;Swan *et al.*,2017:103). One side of the complex bordered the beach and it was in a convenient place for loading ships (Whitehouse,1968:12). Related to glass working activities was the kiln with the small rubbish pit, uncovered inside a yard, containing debris of glass (drops, trails, glassy slag) and fragments of vessels (Whitehouse,1968:12;Swan *et al.*,2017:103). For a long time it was suggested that glass might not have been produced there due to the absence of conclusive evidence and that the kiln and the glassy material was related to the glazing activities of the potters (Whitehouse,1968:12;Swan *et al.*,2017:103). Although ambiguous without controlled excavations, an archaeological survey in a large mound, known as Tul-I Shisheh (mound of glass), seems to indicate the existence of a 9th-12th century AD glass factory in a large area (100m2) covered with glassy slags and debris (Whitehouse,1968:18;Swan *et al.*, 2017:103).

Whitehouse, who visually examined glasses from Sīrāf, was of the opinion that 90% of the glasses with the thinly blown walls and bubbles, made by a blue and green glass, were probably produced locally (Whitehouse,1968:18;Swan *et al.*,2017:103). A glance through the excavated glass material shows that the green glass sometimes has a distinct yellowish tinge and the weathered surfaces were opaque grey-black while the blue glass has a uniform light cobalt tinge and the weathered surfaces were blue-black (Whitehouse,1968:18). Blue and green glass was common during Period 2 at Sīrāf (AD 825-50 to AD 977-1055), while it was rare in the period before AD 825-50(Whitehouse,1968:18). The ornamentation was common, and few fragments were created by cut and mould blown techniques (Whitehouse,1968:18). Vessels created from that type of glass were bowls, beakers, goblets, sprinkles, alembics, lamps and bottles (Whitehouse,

1968:19;Swan *et al.*,2017:103). The glassworkers in Sīrāf were not restricted to the use of only one type of 'primary' glass as there were some differences in those glasses, according to macroscopic criteria, from the remaining small amount of high-quality bubble-free colourless glass, often bearing cut or carved decoration (Whitehouse thought the glass of East Persian type) and from the mould-blown and carved decorated 'Egyptian' glass (Swan *et al.*,2017:103).

CHAPTER 3

THE TRADE OF GLASS IN THE EARLY ISLAMIC PERSIAN GULF

3.1 Glass trade in the Early Islamic Persian Gulf

In the Umayyad and ´Abbāsid period in some of the hubs in Egypt (Cairo), Levant (Beirut), Syria (Damascus, al-Raqqa), Iran (Nishapur), and Iraq (Sāmarrā, Ctesiphon, Baṣra) there would have been extensive industrial complexes, as the previous chapters show, that were producing raw glass or vessels made from it because of the great demand for local and foreign commodities. The glass was exchanged and intensively traded in a range of ways between these regions and even far away across the Indian Ocean to Africa, South East Asia and China (Kröger,1995:8;Tanichi,2004;An,1991;Saitowitz,1996;Li *et al.*,2016;Henderson *et al.*,2016). For years, the general thought was that only certain types of early Islamic glass were traded as a luxury or costly item or as a diplomatic gift due to complex networks of the political envoys. Later archaeological research pointed out that almost all types of early Islamic glass were exported (Kröger,1995:8,Henderson *et al.*,2016). The glass could be carried via several routes, - land routes like the Silk Road that went from China to the Mediterranean region (***Figure 3.1.1***) and- the caravan route that came from the desert and went to the east to Iraq and then to the Persian Gulf coast, and into a marine route like the Spice route (**Figure 3.1.2**) or the Red Sea route or the Persian Gulf route. The glass that was carried from two of the main ports of the Persian Gulf, Başra and Sīrāf, either through the Silk Road, or through the marine route to the Arabian Sea, to India, to Northern Africa and then to East Asia, is the focus of Chapter 3. The exact trade route is often neglected mainly because within the Muslim world, the long and short distance itineraries overlapped and the land trade routes made contact with the marine routes (Hourani,1995:21;Saitowitz,1996:53). Consequently, the glass trade from Baṣra and Sīrāf will be studied as a virtual network rather than a physical road. The reconstruction of glass trade is a difficult task and will be presented in Chapter 6.

Any history of glass trade in the Persian Gulf will necessarily focus on its main ports, Baṣra and Sīrāf. Baṣra and Sīrāf were the chief ports connecting the waterways of the Indian Ocean with Baghdad, the centre of the Islamic Empire (Hourani,1995:64). Those ports became important

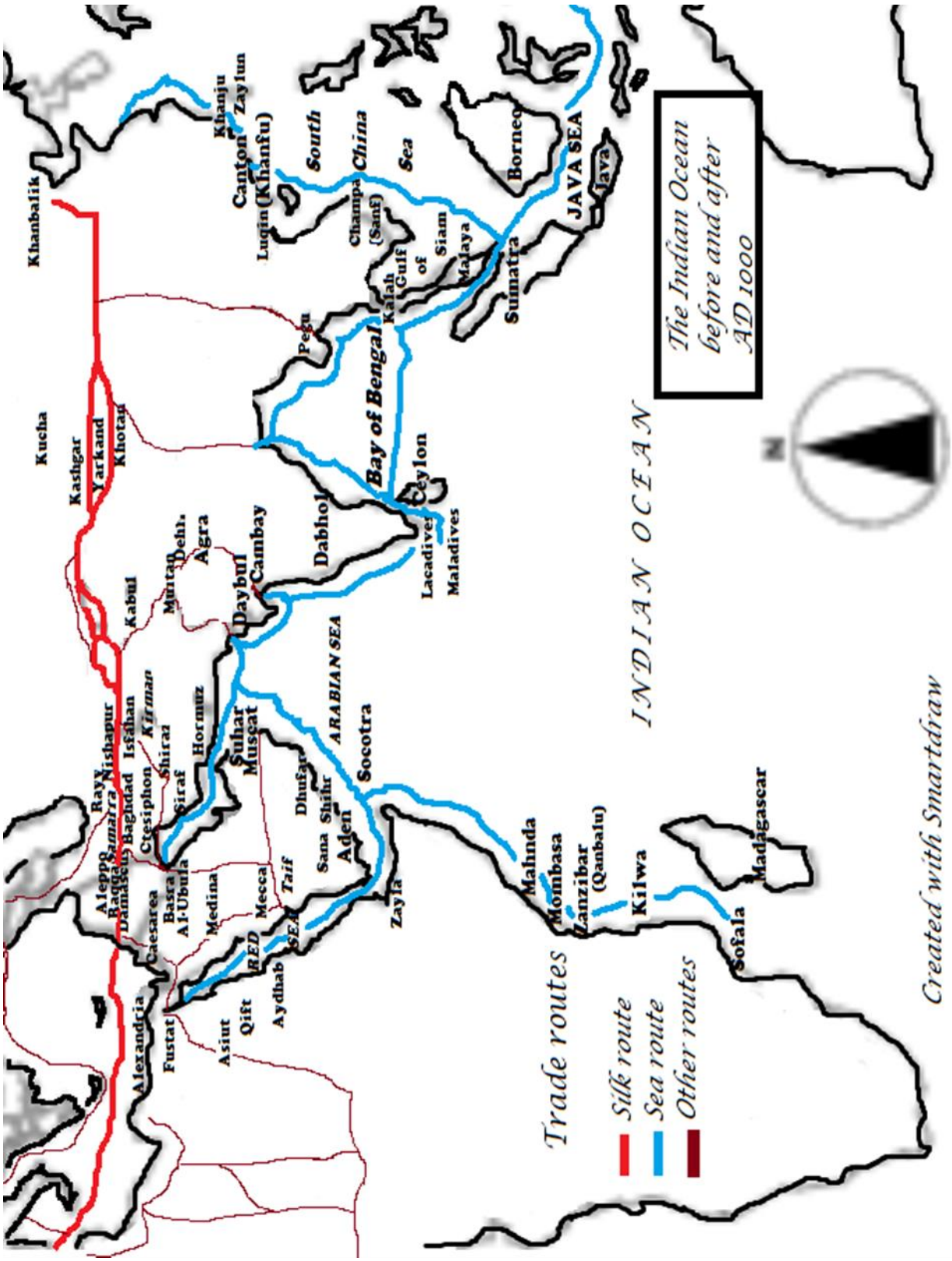


Figure 3.1.1: The Silk route before and after 10th century AD.

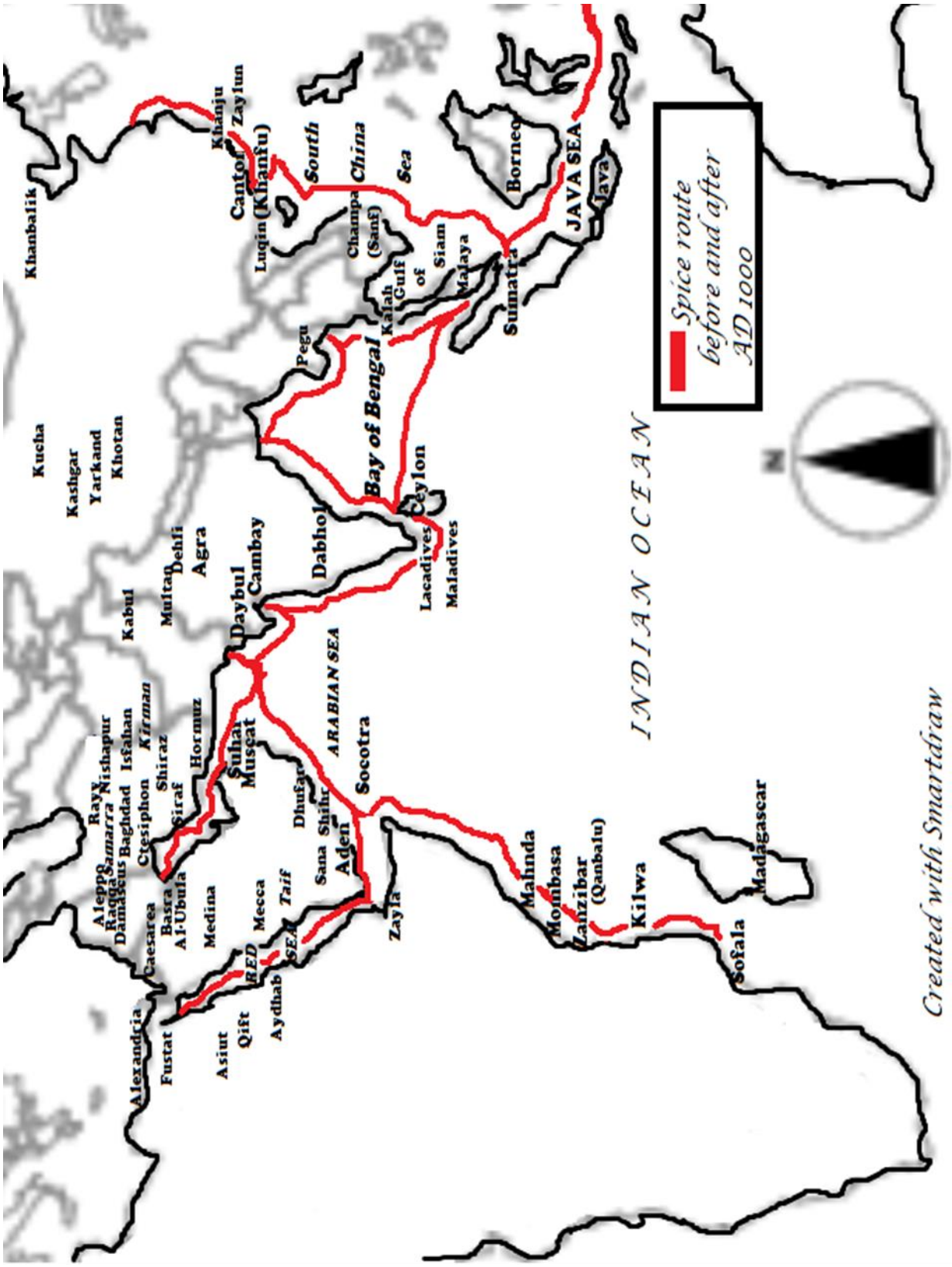


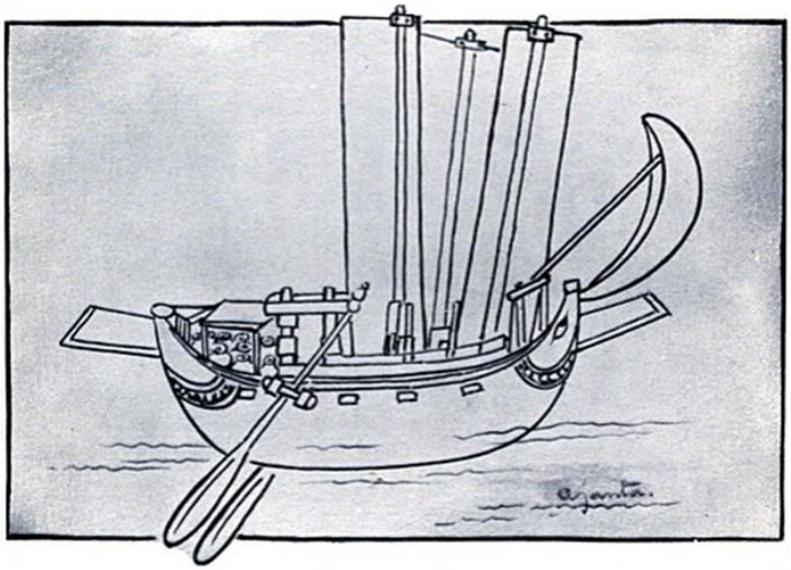
Figure 3.1.2: *The Spice route before and after the 10th century AD.*

entrepôts connected to each other and to the mainland; all kinds of commodities, ideas, and ways of thinking were passed through those ports back and forth (Potter,2009:4).

The 7th and 8th century AD merchants and traders of Başra and Sīrāf could carry cargo that came from seagoing ships, such as silks, porcelain from China, peppers, as well as other spices, aromatics, luxury goods, camphor, muslin from India and the Far East, tin from Malaysia, slaves, gold, ivory, teakwood, ambergris, and tortoise shell from Africa. These could be taken up river to Baghdad or could be exchanged with cargo coming from the mainland (Ricks,1970:343;Hourani,1995:64). The ships exported antimony, rugs, precious stones from Syria (al-Sham), Egypt, India or the Far East, as well as local products from the Persian Gulf such as pearls, cotton, linen, woven fabric, wool, perfume, horses, carpets, pottery and glass (***Figure 3.1.3***). These were exported all the way to China and Africa (Daryaee,2003:3). Many glass artifacts have been found at sites with which Baṣra and Sīrāf had connections. But this relatively simple model of long-distance glass trade is not supported by the early medieval sources.

The early medieval geographers and travellers, who are equally valuable, provide general information about products, merchants, harbours, coasts, stages of voyages, captains, seamen and their languages (Ricks,1970:344;Hourani,1995:67;Daryaee,2003:3;Whitcomb,2009:72). There are occasional references (Wilkinson,1982) to groups of merchant families within a governmental authority such as the Muhallabi, and merchants within religious movements such as the Ibadis, as cited in Whitcomb (Whitcomb,2009:72). Al-Nazar ibn-Maymun of al-Baṣra h (Lewiski,1935) is one of these Ibadite merchants who claims to have been visiting China. Abu-Ubaydash is another Ibadite merchant of Umani origin that bought aloe wood to China in the middle of the 8th century AD (Hourani,1995:63). Two Ibadite sources, Abu'l-'Abbas Ahmad b. Sa'id al-Dargini and Abu'l-'Abbas Ahmad b. Sa'id al-Shammakhi (Lewiski,1935), as cited in Ricks (Ricks,1970:344), suggest that in the early Islamic period the Persians introduced the Arabs to the trade with China. The existence of a considerable number of Ta-shih (Arabs) and Po-sse (Persian-Arabic speaking Moslems from Iran) traders in the city of Kwang-chou (Canton) (Hirth,Rockhill,1911:114) in China are recorded in the Chinese annals (History of the T'ang), referring to an incident in which they sacked and burned the city together in the year 758 (Ricks,1970:344;Hourani,1995:62).

Apart from stories of merchants, a number of names and histories of captains of Sīrāf are mentioned by the Iranian Buzurg ibn-Shahriyār of Ramhurmuz (al-Rāmhurmuzī,Buzurg b. Shahriyār,1966) in the book Kitāb 'Ajā'ib al-Hind (Hourani,1995:65,Whitcomb,2009:174).



A SEA-GOING VESSEL.
(From the Ajantā Paintings.)

Figure 3.1.3: *Fresco painting in a cave at Ajanta (perhaps A.D. 630) shows a vivid representation of the ceremonial attending the presentation of their credentials by the Persian envoys.*
(https://en.wikisource.org/wiki/Indian_Shipping/Book_1/Part_1/Chapter_2)

Buzurg (al-Rāmhurmuzī,Buzurg b. Shahriyār,1966), cited in Hourani (Hourani,1995:68), was a sea captain who collected tales of life from sea captains and merchants travelling from Sīrāf, al-Baṣra h and ʻUmān to India, the Far East and East Africa. Abu-Zayd al-Ḥasan ibn-al-Yazīd (Abu-Zayd al-Ḥasan ibn-al-Yazīd,1845) from Sīrāf, cited in Hourani (Hourani,1995:68), provides information in AD 916 about seaman and merchants of Sīrāf. There is a special interest also in seamen and their language, expressed in AD 947 by geographer Al-Mas'udi (Masudi,1861) in his work Muruj al-Dhahab wa Ma'adin al Jawhar, cited in Hourani (Hourani,1995:67). The mainly geographical information is based on previously listed sources and on Al-Mas'udi's - personal experience travelling from Sīrāf to India, to the Maldive islands and to the land of Zanj in East Africa (Hourani,1995:67;Saitowitz,1996:59;Whitcomb,2009:174). Al- Masʻudi (Masudi, 1861), cited in Saitowitz (Saitowitz,1996:59), says that traders from Sīrāf visited the Maldive islands, and the same story is reported again in AD 1030 by al-Birouni (al-Birouni,1989). The story given by Masʻudi of Sīrāf of the merchants trading with the East African littoral is mentioned by Ibn Hawqal (Abu al-Qasim Muhammad ibn Hawqal,1086) later in AD 96, cited in Ricks (Ricks, 1970:351). Ibn Hawqal (Abu al-Qasim Muhammad ibn Hawqal,1086) met a wealthy

merchant in Başra Ahmad ibn 'Umar al-Sīrāfi, whose ships carried spices, precious stones, and perfumes from Zanzibar (Ricks,1970:351).

The stages of the voyages from the Persian Gulf to China has been provided by different geographers, cited in Hourani (Hourani,1995:68) and Whitcomb (Whitcomb,2009:174), such as Ibn-Khurdadhbih (Ibn-Khurdadhbih,1879) in AD 850, the author of Akhbar al-sin w-al-Hind and an unknown traveler in AD 851. In the 9th century AD, there are references to the Persian Gulf trade with Africa. An unknown Chinese scholar says that the Iranian traders dominated the sea routes round the Horn of Africa (Sheriff,2009:174). The noted geographer, Ahmad al-Muqaddasi (al-Muqaddasi,1906), cited in Whitcomb (Whitcomb,2009:72), in his 'Ahsan al-Taqasim fi Ma'rifat al-Aqalim' book (late 10th century), mentioned the urban settlements of the Persian Gulf providing information about their production and the relationships with other places. Returning to glass as a trade item from the Persian Gulf ports, if we solely relied upon the above occasional notes and the descriptions of the geographers then much of the Persian Gulf glass trade would be invisible.

3.2 Possible destinations of glass from the Persian Gulf on China and Southeast Asia

From the T'ang dynasty (AD 618-907) onwards, a number of imported glass vessels from Western Asia were brought to inland and coastal port cities in Southeast Asia (Laem Pho and Ko Kho Khao, Thailand and Java Sea), Japan (Shōsōin, Toshodaiji), China (Shaanxi province (north of Fufeng), Jixian, (Tianjing), Chaoyang, (Guangzhou) and Naiman, Inner Mongolia (Toshihiko,Fukai,1964:xiii;An,1987:9;Fukai,1977:39;An,1991:130134;Brill,Fenn,1992;Krőger, 1995:8;Carboni,2001:80;Tanichi,2004;An,2009;Hokuraetal.,2009;Jie,2010:183;Vahidzadeh,Af rud,2010;Tanichi,2010;Dhanmanonda *et al.*,2012;Nakai,Shindo,2013;Stargardt,2014;Li *et al.*,2016;Priestman,2016:22;Henderson *et al.*,2016:17). The richness of early Islamic glass was the first actual evidence of trade between the Islamic world and Southeast Asia, Japan and China that reveals the gap in the literary sources. For years, it was thought that large quantities of the early Islamic glass were produced before the 9th century AD near the Silk Road route (al-Raqqa) especially near the Iranian plateau (Nishapur) (Fukai,1977:39,45;Simpson,2007:60,79; Jie,2010:183;Stargardt,2014:37;Priestman,2016:25). Then from there it was thought that the glass passed through Central Asia and China. Nowadays there is a strong evidence, coming from chemical analyses, that large quantity of glasses, especially the vessels with scratched decoration, were produced in central and southern Iraq (Sāmarrā, Baghdad, and Baṣra) and might actually have entered Southeast Asia, Japan and China through Başra or Sīrāf via the maritime route before the 9th century AD (Fukai,1977:39,45;Simpson,2007:60,79;Stargardt,2014:37; Priestman,2016: 25). However, until today, questions related to glass trade are yet to be properly resolved. The investigation of the current subchapter will therefore present the recent available information and the discoveries of early Islamic vessels dating from the 7th until the early 11th century AD that might have been exported as trade products from Baṣra and Sīrāf.

The archaeological occurrence of a small quantity, before the 9th century AD, of glass vessels- as a product mainly of the overland "Silk Road", and a significant quantity of glass vessels, after AD 1023, as a product of the sea "Silk Road" from the Iranian plateau and Iraq, led to the plan for a series of excavations and expeditions (An,1991:5;Tanichi,2004;An,2009;Hokura *et al.*, 2009; Borell,2010;Dhanmanonda *et al.*,2012;Nakai,Shindo,2013;Stargardt,2014;Li *et al.,*2016; Priestman,2016:22). In the summer of 1964, the Fourth Iraq-Iran Archaeological Expedition was organised by Tokyo University, carrying out excavations in Northern Iran (Toshihiko,Fukai, 1964). Since then, a series of excavations followed. Compared to what the excavations brought

to light about the trade of glass to the furthest eastern extremity of the Old World, our knowledge is still quite sparse. For instance, little is currently known about the movement of glass that must have been manufactured in Baṣra during the early Islamic period and which type of Iraqi or Iranian (or even Syrian, Levantine, or Egyptian) glasses must have been shipped or transported to Sīrāf to be supplemented or not with products of local kilns for the overseas trade. In the Arabic literature, there are references from writers, such as Sulayman al-Tajir (851)(1733) based at Baṣra (Iraq), -Abu-Zayd (1733) based at Sīrāf, and the historian al-Mas'udi (1861-77) cited in Guy (Guy,2011:21) that wrote largely about the two centres of the Arab-China trade but there are no references of glass trade. The previously held perspectives of the historical significance of maritime long-distance trade with the east has been changed by the recent available information on shipwrecks, ceramic and glass chemical analysis (An,1991:5; An,2009:394;Guy,2011:19;Stargardt,2014:38; Priestman,2016:2).The new findings have allowed a radical reappraisal of the maritime Silk Route. It has been long known that pottery originating in the Persian Gulf region and glass were exotic imports, especially among the coastal elite in China and usually were included among grave goods in China and Japan (***Figure 3.2.1***, Guy,2011:25-27). Nowadays the distribution pattern of large storage jars or amphora type Persian jars that were most probably produced in Baṣra shows the international trading system between Baṣra and Sīrāf ports with a region from coastal China to the western coast of India (Guy,2011:25). Large storage jars (probably Baṣra ware), along with Sasanian and early Islamic glass reached as far as Japan, at the Saidaiji temple in Nara, dating from AD 768 or later (Guy,2011:25). The new distribution pattern of ceramic led to the revaluation of the trade mechanism and the exchange systems of early Islamic glass and chemical analyses of some early Islamic glass (Hokura *et al.*,2009;Priestman,2016: 2;Li *et al.*,2016).

Few results of chemical analyses are published, but in the absence of these, authoritative written sources take on significant additional importance. Substantial attention will be paid in this chapter to luxury glasses, although different types of early Islamic glasses were traded eastward and have been excavated in tombs and crypts in China, especially Inner Mongolia and Liaoning, and Japan. From these excavations there are available results from chemical analyses of major and minor elements of early Islamic glasses. Attention will be drawn to the newly available information on the maritime glass trade from shipwrecks, such as Intan (AD 930-950) and Cirebon (AD 930-960). There are no results from chemical analysis of glass found at shipwrecks in Southeast Asia and China. Based on stylistic considerations, the early Islamic glass as cargo



Figure 3.2.1: *Storage jars with turquoise glaze Iran or Iraq. At the right, amphora type storage jar, Baṣra, discovered in the royal tomb of Liu Hua, Fujian (Guy,2011:27).*

ballast found on shipwrecks can shed light on which types of vessels were traded, and if there is a probability that they were traded from Başra and Sīrāf ports. It is hoped that valuable information about numerous issues will be unlocked by the chemical analysis of the current research and that it will become intrinsic to the broader debate concerning the use of the sea Silk Route before the 9th century AD. A number of possible scenarios might be envisaged. The study will focus up the year AD 977, when an earthquake destroyed part of the city of Sīrāf and the port declined (Gray,1963: 13;Whitcomb,2009:78;Whitehouse,1979). In AD 906 there was a vacuum in the Persian Gulf trade, with the demise of the Tang dynasty in China and the Fatimid conquest of Tunisia. After the Fatimid conquest of Egypt (AD 969), al-Fustāt gradually replaced Baghdad, the once magnificent city, and became the centre of wealth in the Islamic world. Then the early Islamic emporia Sīrāf, along with Mantai and Bambhore were supplemented by new ports and the trade routes were transferred to the Red Sea (Saitowitch,1996:20).

The first half of the 7th century AD was characterised as an era of significant economic change in the Persian Gulf, with a surprising growth of commerce and maritime trade with Southeast Asia, China and Japan (Whitehouse,1979:867;Hourani,1991:61;Whitcomb,2009:72; Dhanmanonda *et al.*,2012:2). Two major historical forces caused the growth of trade; the establishment of the T'ang dynasty in 618 by the Emperor Li Yüan and four years later, on July 16, 622 the migration of the Prophet Muhammad b. Abd-Allah to Medina (Whitehouse, 1979:867,Hourani,1991:61;Liu,2010:88;Dhanmanonda *et al.*,2012:2). Under the Tang dynasty (AD 618-907) China, with its expansionist mentality, quelled the nomad tribes in Central Asia and interacted there with ´Abbāsid Iraq, conducting trade along the desert Silk Road (***Figure 3.2.2***, Gray,1963:14;Strathern,1993:33;Raby,2011:xii). The relative political stability resulted in the travel of trade goods between west and east on a larger scale than ever before (Gungwu,2011: 4). Caliph al-Mansūr in AD 762, taking into consideration the great importance of trade with China, founded the ´Abbāsid capital Baghdad in a strategic location near Tigris River with economic advantages so nothing could separate the ´Abbāsid court from China (Raby,2011:xii). The foundation of Baghdad, as well as the rise of Baṣra and Sāmarrā on the Tigris River as luxury production and consumption centres enhanced the attraction of the Persian Gulf trade (Gray,1963:14;Hourani,1995:64;Liu,2010:98). The most interesting luxury product that travelled eastward was glass. Glass in China considered to be a luxury item (Gray,1963:14;An,2010:177;Zhiyong,2010:197;Nakai,Shindo,2013:445;Stargardt,2014:44).The Chinese preference to glass was mainly because the early Islamic glass was of extremely good quality and as well as clear and transparent, but also because it was considered mysterious (An, 2010:177). High quality glass was rare in China until the late T'ang period, although China could produce highly quality glazed ceramics (Stargardt,2014:44).

Baṣra must have been a centre of production of the finest glassware in the early and most important period of Islam but there are no recorded finds (Ettinghausen,1942:6). The question of whether glass was exported eastward from Baṣra is difficult to answer. The main route by which glass travelled would be the land route, the old "silk route" through Central China (Gray,1963:13). Glass could travel with camel caravans carrying exotic commodities until the gates of the Great Wall (Liu,2010:87). However, if Baṣra could export glass eastward during the 7th century AD this would certainly be luxury types of glass. The route was so long and transport at a distance from the place of origin of these glass artefacts was so costly that this greatly increased the values of the artefacts (Gray,1963:13). But why was glass from Baṣra invisible in the archaeological excavations in the east? The answer to the question is that there is



Figure 3.2.2: *Silk route travellers would have encountered many Arab markets such as that one on the above 19th century painting (Strathern,1993:33).*

no evidence whether the glass was produced there and if so which were the types, forms and decorations.

Before the 8th century AD the glass trade by the overland route to China must have been on a comparatively small scale, so it is very difficult for glass produced in Baṣra to be traced in the archaeological excavations (Gray,1963:13). The journey to China was extremely difficult due to the extreme climate of the Central Asian deserts, and only small quantities of glass could travel (Gungwu,2011:9). The route began to be more and more dangerous for the merchants, due to a series of events across Asia (Gungwu,2011:9). For nearly 100 years between AD 763 and 851 there was a severance of the route by the Tibetan conquest in Central Asia (Gray, 1963:14). The sea route to China was also long and hazardous (Guy,2011:27). In AD 717, most of the ships of a convoy of thirty-five Bosi ships that sailed from Sri Lanka to Palembang were lost at sea (Guy,2011:27). With this background, we can now search for luxury glass that might be produced in Baṣra only among the costly glass, in the form of vessels that came to China and Japan and became a treasure in tombs and crypts.

3.2.1 China and Inner Mongolia

In the last few decades, many early Islamic vessels have been frequently reported in tombs and crypts in China and Japan. The earliest glass of the period of our interest is dated to AD 741 and is a bottle that bears applied decoration (Tanichi,1991:40). The bottle was uncovered at the Stupa of Qingsham Temple, Shanxi but there is no defining indication of its exact production place (Tanichi,1991:40). At the Nanyue Kings' Palace a typical Islamic cylindrical bowl or cup clear, with faint tinges of yellow and green, was uncovered in the Tang layer (AD 618-907) during the excavations conducted in 2000 (An,2010:177). The cup, with vertical walls and a kick-base that bears the pontil mark, had parallels with Nishapur glasses (An,2010:177). There can be little doubt that the most important glass finds come from the crypt of Famen Temple in province Shaanxi in North China and have been published mainly by An Jiayao (An,1991;Brill,Fenn,1992;An,2009). The importance of the finds is great not only because they show which type of vessels were traded but also because they provide terminus ante quem dates (Krőger,1995: 8;An, 1991:5;Tanichi,1991;Brill, Fenn,1992;An,2009;Jie,2010:183).

In 1988, the archaeological excavations at a stupa with a crypt in Famen Temple in the north of Fufeng County, Shaanxi province unearthed eighteen intact Islamic vessels among Mi'se porcelain, gold and silver ceramics and silk (An,1991,2003;Jie,2010:183;Li *et al.*,2016:157). The crypt was built in AD 874 to house the finger bones of Sakyamuni, but it collapsed several centuries later (Carboni,2001:80;An,2003). During the Ming Dynasty (1368-1644 AD), it was replaced by an octagonal pagoda, which in 1981 collapsed due to heavy rains, offering the opportunity for the archaeologist to excavate the stupa (Carboni,2001:80;An,2003). Somewhat unexpectedly, almost all the glass finds came from the early Islamic world, as tributes from foreign emissaries (Jie,2010:183). Six shallow vividly coloured (dark blue transparent) dishes with an irregular bottom and slightly splayed rim were uncovered (An,1991:123;Brill1992:254; Krőger,1995:117;Carboni,2001;An,2003;Tanichi,2004:40;Jie,2010:187;Li *et al*,2016:160). The dishes described above were placed in the crypt in the fifteenth year of the Xiantong reign (AD 874) as an offer by the Emperor Xizong to the Tang dynasty. Two of the vessels showed gilding in the incised lines, which was unusual (An,1991:123;Krőger,1995:117). All the dishes vary in height and diameter (Krőger,1995:117). In addition, they are decorated with different floral and geometric patterns (Jie,2010:187). Identical decorative patterns such as ropes, vines, sunflowers diaper and five-petaled leaves (which according to Brill, resemble the hemp plant, Cannabis

sativa), have been found in two glass fragments uncovered in Nishapur and led the researchers to the suggestion that all the dishes were products of the same workshop (***Figure 3.2.1.1***, Metropolitan Museum of Art, An,1991:123;Brill, Fenn,1992:255;Krőger,1995:117;An,2003).

For a number of years, it was thought that the dishes must have come from Nishapur (Jie, 2010:187). However, fragments with similarities in decorative methods have been excavated in different places in the Islamic world such as al-Raqqa, al-Mīna, Nessana, Susa and Sāmarrā (Krőger,1995:116). Whether the workshop that produced the vividly coloured glass with incised fine decoration was in Nishapur or in another Iranian city, or whether Nishapur was a stop along the trade route was a subject under investigation. In 1992, Brill and Fenn analysed nineteen samples with scratch decoration (Brill,Lenn,1992;Brill,Fenn,1992:254). The analyses show that many samples (15) belong to the soda-lime natron type glass and four to the plant-ash type. Hence, it was impossible to say with certainty whether the samples found in China were made in Egypt or elsewhere around the shores of the Mediterranean (natron type) or was a plant- ash type produced in Iran or Mesopotamia (Brill,Fenn,1992:254). Brill and Fenn judging only by the decorative motifs suggested that the products might have been made in or near Nishapur (***Figure 3.2.1.2***,Brill,Fenn,1992:254;Alain,2015:28).

The answer to this question came recently in 2016, by the scholar Li and his colleague. They used a portable XRF spectrometer to chemically analyse samples from the Famen Temple (Li *et al.*,2016). With the exception of one scratch sample, chemical analyses disprove Brill and Fenn's suggestions that the glass might have been made in or near Nishapur (Li *et al.*,2016:158). The analysis shows the existence of four different groups. The researchers compared the results with other results from the contemporaneous Islamic world to investigate the place of production (Li *et al.*,2016:158). Carboni's suggestions to search for the origin of the entire group farther to the west in the Syrian regions seem to be likely (Carboni,2001:80). The scholar proposed Syria as a possible place of production (Li *et al.*,2016:175). For years, the entire group was attributed to Iran, especially Sāmarrā, by the art-historians. Four scratched- decorated vessels from the Famen Temple, according to the chemical analysis, have a very close relationship with those from Nishapur but only one was probably made there (Li *et al.*,2016:175). All the other samples were made in a specialized production site or zone with other scratched decorated vessels, perhaps in Syria (Li *et al.*,2016:175). An interesting result from the chemical analysis was the yellow transparent bottle with a narrow neck and dish-shaped mouth. According to An Jiayao, the yellow bottle had no exact parallel in the Islamic world (Brill,Fenn,1992:255;An,2003). There were some features such as the applied molded disks, thread and irregular star decoration that were said to come from the eastern Mediterranean area but chemical analysis shows that the



Figure 3.2.1.1: *Scratched decorated plate excavated in Nishapur (Metropolitan Museum of Art).* (https://www.metmuseum.org/art/collection/search/449824)

bottle probably had an Afghan origin because of the high level of potassium (Li *et al.*,2016:174). Two undecorated pale yellow glasses were in the same group (Li *et al.*,2016:174).

Lustre-painted glass with a yellow and black surface decorated with poppy patterns was a subject of great interest in the study of Islamic glass vessels from the Famen Temple (***Figure 3.2.1.3***, An,1991:129;Kroger,1995:115; Jie,2010:186;Li *et al*,2016:161-163). The superb quality and extremely rare type, whether it called enamel-painted or lustre-painted glass, belongs to the same chemical group as undecorated cobalt blue vessels and as a molded decorated beaker (An,1991:129;Kroger,1995:115;Li *et al.*,2016:163). The decorated beaker with rhombus and double circle patterns had an interior ring, similar to one uncovered in Iraq and shares features with other beakers found in al-Raqqa (Syria), Egypt, Bijān Island (Euphrates, Iraq), Takth-i Sulaiman (Iran) and Pella (Jordan) (Krőger,1995:56;Tanichi,2004:40;Li *et al.*,2016:171). The fragment with lustre-painted decoration bears two pomegranate flowers in the interior (Jie,



Figure 3.2.1.2: *Scratched decorated plate from a crypt of Famen Temple (Famensi Museum)(Alain,2015:28).*

2010:186). The decorative pattern was black in a yellow background colour (Jie,2010:186). Parallels can be found in Nishapur, Sāmarrā and Takht-I Sulaiman (Kroger,1995:115;Li *et al.*,2016:175). According to Ettinghausen, fragments of lustre-painted glass must have been produced in Iraq, possibly in Başra, along with lustre-painted pottery, and then the technique passed to Egypt and Syria (Ettinghausen,1984:853). Chemical analysis shows that the above group was not a product of the Iranian and Iraqi workshops (Li *et al.*,2016:175). The composition of the glass was low in potassium and magnesium, which is the typical composition of the early Islamic natron glass from Egypt and Syria, and was different from the type that is thought to have been produced in Iraq with a composition high in strontium (Shindo,2003:176). The place of its production must be searched in one or more workshops that would have been in Syria or Egypt (Li *et al.*, 2016:175).



Figure 3.2.1.3: *Lustre-painted glass with poppy patterns in Famen Temple (Li et al., 2016:161).*

The lustre-stained bowl with the characteristic rim which is folded outward has parallels with seven pieces of a monochrome type of glass painted of deep blue, pale bluish green, pale green and pale purple uncovered in Rāya by the Middle Eastern Culture Centre in Japan (Shindo, 2003:174). The Rāya bowls, like the Famen Temple glass, is also thought to have been brought from Syria or Egypt (Shindo,2003:177). The similarity of Rāya glass with that of the Famen Temple glass, and of the ports Ko Kho Kho (Malay Pensinsula) and Ku Lao Cham (Vietnam) led the researcher Shindo to suggest that the glass was loaded on a ship in the Rāya port city with a destination to the east (Shindo,2003:177). Although the most active port, between the 9th and 10th century AD was Sīrāf, Shindo believes that glass must have travelled from the Red Sea route (Shindo,2003:177). So far, the investigation dealing with early Islamic glasses from the Famen Temple show Egyptian, Syrian and Afghan origin. Two routes were also suggested: the mainland Silk Route and the Red Sea Route. The question readily arises whether there are any indications

in the Famen Temple of glass with Iranian or Iraqi origin. An indication of an Iranian or Iraqi origin can be gathered from a group of colourless glass with geometric decoration (Li *et al.*,2016: 174). According to Lamm, the decorative technique of the cups was attributed to Egypt or Persia in the 9th century AD. For a long time it remained uncertain for art historians which of the two origins was the actual one. The answer comes from chemical analysis results. Egypt was not the place of their production (Li *et al.*,2016:174). The cups have a similar composition to colourless glass with facet-cut and linear-cut decoration of the early Islamic world and were made from an Iranian or Iraqi glassmaker. This glassmaker blew glass into a mould with countersunk patterns in the first stage of blowing glass, as in the Roman period, and continued blowing, tooling and twisting in the second stage after the design was fixed on the surface (An,2003;Krőger,1995:85).
During the Song dynasty (AD 960-1279), an era of significant economic changes with the growth of commerce and maritime trade eight Islamic glass vessels were uncovered from the Stupa no.5 of Dingxian Hebei (An,1987:9;An,2003;Tanichi,2004:40). The samples were precisely dated to AD 976 (An,2003;Tanichi,2004:40). Among the samples, the most important for the current research was a flask with cut decoration, provide valuable information about the development that followed, but also the flask was important because its decorative technique was widely developed in Iranian (Nishapur) and Iraqi (Ctesiphon, Baghdad, Baṣra) workshops (An,2003; Henderson *et al.*,2016). Early Islamic glass of outstanding quality continued to be found in tombs in Inner Mongolia during the Liao dynasty. The northern part of the Song dynasty was invaded in AD 1004 by the Sixth Emperor, Yelu Longxu (r. AD 982- 1031) and since then the Song dynasty sent luxury annual gifts to the Liao dynasty (Tanichi,2004:40). Not only does the flask, as part of a group of five cut and engraved carafes uncovered in China, In the Qinglong tomb no.3 of the daughter of the Emperor Yelu Longxu in Naiman (Inner Mongolia), early Islamic glasses of an outstanding quality were found depicting the high level of Caliphs glassworks (Krőger,1995:130). The wide bowl with relief-cut decoration including a row of twenty-eight pyramid shaped spikes, is a characteristic example (Krőger,1995:130,An,2003). The bowl was among seven pieces of glasswares and is dated precisely in the seventh year of Katal's reign (AD 1018) according to the epitaph which refers to the death of Princess Chenghuo (An,1987:9; An,1991:130;Krőger,1995:130;Carboni,2001:148;An,2003;Tanichi,2004:40).
So far it was not clear if glasses from our area of interest could be found among glasswares such as the brown cups with the applied threads, the jug decorated with applied prunts and threads, the carafe with the frieze of lozenges and engraved geometric devices, the bottles with the raised rings and long necks, and finally the carafe with the cut design in the neck (An,2003). The two brown pitchers found in the tomb of Princess Chenghuo (AD 1018), one undecorated and the

other decorated with applied threads, have interesting parallels with an undecorated pitcher of Iranian origin in the Kuwait Museum, a fragmentary pitcher uncovered in Nishapur and a similar pitcher dated to AD 1019, unearthed in the province of Liaoning (Carboni,2001:148). The pitchers are of the same type and have similar flattened bodies. In a trial to reveal the actual origin, chemical analysis has been conducted by the Chinese Research Institute of Buildings Materials on three samples, among them the pitcher with the L-shaped handle (Tanichi,2004:44). The results of chemical analysis when compared with data from chemical analysis conducted by Brill (Brill,1999) of various Islamic glass vessels show that the pitcher with the openwork handle fits with samples from the Nishapur Neighbors and Afghanistan, the flask fit with samples found at Takht-i-Sulaiman and the conical neck with samples found at Nishapur, Sīrāf, Takht-i-Sulaiman and Afghanistan (Tanichi,2004:44). But there was no further indication. A similar pitcher with an L-shaped handle of Islamic provenance has found at Qinglong tomb, at the Guyingzi Tomb of Queen Dowager of State Chen (Tanichi,2004:40).

In the wide variation in the type of decoration, such as from the simple undecorated bowls through to vessels that are mold-blown, applied, incised and painted, the most popular vessel travelling eastward was one with wheel-cut decoration. Two early Islamic flasks with cut decoration have been found at the Pagoda of Huinguang Stupa, Ruian and the Stupa of Wuwei, Anhui, dated to AD 1034 and 1036 respectively (An,1987:9). Flasks of that type appear to be products of Persia or Mesopotamia but there is no evidence in chemical analysis results (Tanichi, 2004:40). In the same period (AD 1032-1054), another type of glass of Islamic provenance was uncovered in the northern pagoda in Chaoyang (An,2003). The glass, which was a double jug with a smaller inside the larger, was found among hundreds of valuable objects (An,2003). In the fourth year of the Quingning (AD 1058), a clear Islamic carafe with oval facets and grooves was found at the Stupa of the Dule Temple in Jinxian, Tianjing (An,1991:134;Krőger,1995: 127;An,2003;Tanichi,2004:40). The carafe belongs to a group of long-necked bottles with cut decoration and a sequence of dots; the bottles bear one or two lines on the corners of the shoulders and the base; An interesting feature is that this type of bottles appears only in specific places, such as local powerful cities of the Islamic world such as Nīshāpūr and Rāya, located in the southeastern part of the Sinai Peninsula (Krőger,1995:130;Shindo,2004:25). According to typological criteria, the carafe was similar in shape and decoration to that found at Nishapur. While its exact provenance has remained for a long time quite uncertain, chemical analysis seems to agree with typological analysis showing that the neck has similar composition with sample 3080 from Nishapur (Kröger,1995:44).

3.2.2 Japan

The early Islamic glasses were transported from remote areas to China, as part of a systematic exchange, and several of them passed to Japan as precious and mysterious items (Priestman, 2016:22). The fact that Japanese people considered early Islamic glass a precious item is obvious by the high-status context, such as imperial and royal places, where many of them have been uncovered (Fukai,1967:23;Nakai, Shindo,2013:450;Hokura *et al.*,2016;Priestman,2016:22). In the Shōsōin temple treasure house in Nara, Japan early Islamic glass, dated to the 8th-9th century, forms part of the treasure of 9000 extremely precious artifacts (Nakai,Shindo,2013:450; Priestman,2016:22). The imperial Shōsōin repository of the Tōjdi-ji temple was constructed around the mid-8th century AD (Priestman,2016:10). The glass of Islamic provenance was found among exceptionally fine quality plant-ash-soda-lime glass with a Sasanian date, which is generally known that have been produced in Persia (Iran) (Nakai,Shindo,2013:450); their origins were a subject of special interest. According to Fukai, even in the 8th century the Japanese did not have the skills to produce high quality glass (Fukai,1977:39); there were also no indications that glass of the specific type was produced in China or the Korean Peninsula (Fukai,1977:39).

Professor Fukai was the first scholar who noticed after World War II, a glass vessel in the Teheran Archaeological Museum similar to the carafe in the Shōsō-in temple, as well as to bowls in the Gilan province (Iranian highlands), as a piece of Amlash treasure (Fukai,1967:8). Then, as a member of the Tokyo University Iran-Iraq Archaeological Expedition in Dailaman, Gilan Province, he studied the glasswares and drew scientific attention in Japan and overseas (Fukai, 1967:8). Comparing the Sasanian glasses with those found in the Shōsō-in temple, those in a religious mound on the island of Okinoshima off Kyshu and in Kamigamo of Kyoto, those in the tumulus of the Japanese emperor Ankan (r.531-35) in Osaka Prefecture Fukai recognized a Persian origin (Fukai,1967:8) But this was not the case for the Islamic glass. The ´Abbāsid glass could have originated in Persia or elsewhere in the Middle East. Studying glasswares in the Shōsō-in temple Fukai observed that the green pear shaped carafe dated to the late Sasanian period and not the early Islamic period in the absence of a curved line from the rim to the body (Fukai,1967:52).

The production of the pear-shaped carafe started initially in Iran but after the 9th and 10th centuries AD widely spread around the Islamic world (Carboni,2001:219). Parallels with the

carafe in the Shōsōin repository can be found in a carafe, nowadays in the Kuwait National Museum, dated to the early Islamic period and in a carafe excavated near Qazvin, dated earlier to the late Sasanian period (Carboni,2001:219). It is noteworthy that a carafe dated to the early Islamic period (because it bears a curvature from rim to body) was uncovered at the Toshodaijii Temple during the excavations in Nara, Japan (Fukai,1977:38;Nakai,Shindo,2013:453;Hokura *et al.*,2016:213). The temple was built in 759 AD, by the famous priest Ganjin (Jianzhen in Chinese), who was invited by Shōmu the Emperor of Japan to train priests and improve Buddhism (Nakai,Shindo,2013:453;Hokura *et al.*,2016:213). The transparent carafe coloured with a light greenish amber was clearly considered Persian in Japan because it was widely known as kohei type (**Figure, 3.2.2.1,**Fukai,1977:38;Nakai, Shindo,2013:453). Parallels can be found in the ruins of reliquary tower in China, in Fustāt (Egypt) and in Jebel Sais (Syria) (Hokura *et al.*,2016:238). The Japanese scholars, reading the Chinese sources and studying the treasures, had conjectured that the carafe originated in Persia or elsewhere in the Middle East, but it was impossible to prove that through chemical analysis (Fukai,1964:8;Fukai,1977:38;Nakai,Shindo,2013:453;Hokura *et al.*,2016:213). The glass was considered precious from historical point of view, containing the Buddha's ashes (Fukai,1964:8;Fukai,1977:38;Nakai,Shindo,2013:453;Hokura *et al.*,2016:233). It was housed in a metallic tower and the rim was covered by the metallic lid (Hokura *et al.*,2016:233). There have been few times when the carafe has been shown to the public (Hokura *et al.*,2016:233).

The first analysis, conducted in 1953, measured the coefficient of the β-ray backscattering and showed that the glass did not contain PhO (characteristic of the Chinese glass). Since it was established by chemical analysis that the carafe had to be imported from Persia or elsewhere in the Middle East a second analysis followed. In 2016, the scholar Hokura and her colleagues published the results from chemical analysis of the vessels in Toshodaiji Temple, as a trial to answer questions related to the origin of the glass. The purpose of their study was to compare the chemical composition of the vessels with 400 analysed samples from the Rāya port, located in Sinai Peninsula (Egypt). Many Chinese pottery vessels were uncovered and It was believed that the West-East trade was carried out though this thriving city (Hokura *et al.*,2016:233). By following up the results from the chemical analysis, one should be able to establish that it was glass used plant ashes as an alkaline source (Hokura *et al.*,2016:239). This type of glass dated from the 9th century and onward (Hokura *et al.*,2016:23). The scholars believe that many glasses were brought from Egypt, Syria or Mesopotamia to Rāya between the 9th and 10th centuries AD, for the maritime trade with the East. Although, the Persian Gulf route was the most active route



Figure 3.2.2.1: *Transparent carafe from Japan containing the Buddha's ashes in glass (Hokura* et al.*,2016:233).*

between the 9th and 10th centuries AD from Sīrāf, the Red Sea Route was also in use after some power changes or changes in the trading system occurred between the 8th and 12th centuries AD (Shindo,2003:177). But before we can proceed to the second stage of examining the possibility of the use of the sea routes for imported early Islamic glasses, one critical issue must be addressed concerning the use of the Persian Gulf route.

By intergrading the new archaeological evidence from many Chinese coastal port cities and Japanese sites in Hakata bay and in Kōrokan, the significant role of the Persian Gulf at this exchange is underscored (Guy,2011:25;Priestman,2016:25). Especially interesting is the fact that the Sasanian cut glass, the 8th -9th century AD glass carafe in the Shōsōin temple and plain fragments uncovered in Kōrokan and other sites in the Hakata bay, was imported to Japan in the same period with turquoise-blue glazed ceramic jars manufactured in Iraq between the mid-8th

-10th centuries AD (Priestman,2016:25). This specific type of ´Abbāsid jar has been reported together with Sasanian and early Islamic glasses of the same nature in high-status locations in Japan associated with religious institutions, such as the temple complex Saidai-jii (765 AD) (Honshū), the temple Kuni-kyō (740-744 AD) (Honshū), the Harunotuji temple in a close proximity in the Hakata Bay, and the temple Kanonjii (Dazaifu) (***Figure, 3.2.2.2***,Priestman,2016:26). The specific type of jars, glazed with a turquoise colour by copper under oxidizing conditions is part of a diverse short-lived traditional production (sometime in the 820s) and its major area of production was somewhere in Iraq (Wood,Priestman,2016:52).

The scholars Masson and Keall (Mason, Keall,1991) attributed the jars close to the port-town of Baṣra although there is no existing evidence (kilns) for the attribution (Priestam,2016:2;Wood, Priestman,2016:52). It is significant is the fact that their increasing quantities in Sīrāf, in different coastal sites of the Indian Ocean and in Japan develop our awareness of about the widespread use of the Iraqi jars (Priestman,2016:22). Whether the turquoise jars were products of a direct exchange from Persian Gulf ships sailing from Baṣra or Sīrāf ports to Yangzhou, Hangzhou, Ningbo, Quanzhou, Zhangzhou and Guangzhou ports or whether they were transported to Japan from the East Asian mainland via local distribution networks, is beyond of the scope of the present study (Wood,Priestman,2016:48;Priestman,2016:22). What is important is that Iraqi jars, with the early Islamic glass, were entering the market of Japan most probably via the sea 'Silk Road' (Priestman,2016:26). That mere fact is on its own remarkable and has recently been recognized. From the written sources, we have a good idea of the information about seafaring activities of the Persian Gulf ports, with seafarers who made annual voyages to China carrying pearls, horses, sandalwood and gemstones. However, the seafarers did not carry glazed jars or glass that were assumed to have a high status, especially among the coastal elite (Pinder-Wilson,169;Guy,2011:25). The fact that turquoise jars appeared in Sīrāf's port together with significant quantities of Tang ceramic underscored Sīrāf's role in this exchange (Priestman,2016:24;Whitehouse,1973; Hodges,Whitehouse,1983:146-149).

The excavation at the Great Mosque in Sīrāf brought to light a substantial amount of green-on-white glazed Guangdong jars and "Dusun" jars produced in inland China (Alain,2015:5). Dusun jars from the inland were transported by waterways, by networks of canals and rivers, to the ports in the south-east Chinese coast for shipping in Sīrāf and elsewhere (Priestman,2016:47). The Chinese green-splashed ware and white-glazed bowls with rolled rim, well-known as Sāmarrā ware, arrived principally at Sīrāf, the major redistribution centre for Iran,

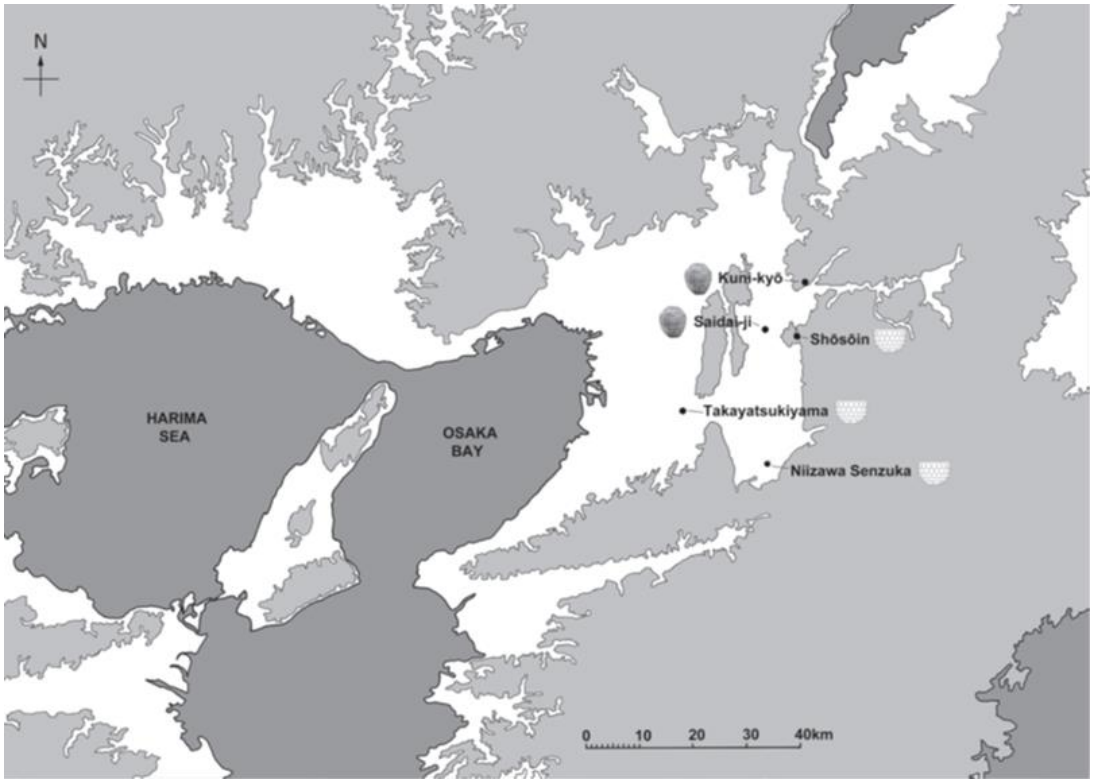


Figure 3.2.2.2: *Turquoise jars and glass bowls in the north part of Japan (Priestman,2016:17).*

to be distributed, by networks of roads and the Tigris and Euphrates rivers, to the ´Abbāsid capital Sāmarrā, where the greatest concentration was found, as well as to Nishapur, to Shiraz, to Kish, to Gurgan, and Fusṭāṭ in Egypt (Priestman,2016:17,47). The same pattern seems to apply to glass and ceramic jars that came from inland from the ´Abbāsid Empire and were transported along rivers to Baṣra and then to Sīrāf (Guy,2011:27). Although Baṣra appears to be a great place of production of turquoise storage jars and possibly glass, it seems that large ships could not come to. Instead, the cargo was transported on smaller vessels to Sīrāf, India, Sri Lanka, Southeast Asia, China, Inner Mongolia, Tibet and Japan (Hourani,1991:68;Stargardt,2014:37). Sīrāf was an important deep water port and the hub of the trade with China. According to Sulayman al-Tajir (1733), Sīrāf was well-placed to receive those cargoes from Baṣra and Arab dhows to be taken eastward (Hourani,1991:68;Guy,2011:21;Wood,Priestman,2016:48). A single ship could carry great quantities of cargoes of diverse origins and could serve a variety of destinations, as the Belitung shipwreck demonstrates (Gray,1963:15;Krahl *et al.*,2011;Stargardt,2014:36).

3.2.3 Shipwrecks

In 1998-99, Michael Flecker excavated the Belitung shipwreck, which was an Arab, Persian or Indian ship (no sign of wooden dowels or iron fastenings) of modest dimensions. It carried significant quantities (60,000 Tang ceramic pieces) of green-glazed storage jars containing ceramic wares of Changsha kilns, dishes and vases of the Yue kilns of Zhejiang province, high-quality white wares of the Xing kilns of Hebei province or the Gongxian kilns of Henan province, blue-and-white wares produced at several kilns, especially at the Gongxian kilns, high-quality green-splashed stoneware, together with rare gold, silver flagons, boxes, cups, dishes, a tiny Near Eastern blue glass bottle and two storage jars probably of the same origin (***Figure 3.2.3.1,*** Alain,2015:5,***Figure 3.2.3.2***, http://www.maritime-explorations.com/belitung.htm). This, was the first evidence for direct trade in c. 850 CE between China and the western Indian Ocean (Flecker,2001:335-6;Alain,2015:580). The wreck lies close to the north shore of Belitung Island between Sumatra and Borneo (Flecker,2000:199). According to Flecker the destination of the ship was likely the Near East, with a higher probability of the Persian Gulf (Flecker,2001a:118;Flecker,2001b:348). Through such failure of the ship we learn more about the shift that followed the 9th century AD from the land route to the maritime Spice route.

The increasing demand in Abassid Iraq for ceramics was probably among the reasons that resulted in that shift. Another reason must have been the quantity of ceramic that a single ship could carry, in contrast with camels (Sackler,2011:xi). New ways to serve the western markets were established by the traders because of a series of events in Asia (the Silk Road and the desert oases became more dangerous) (Sackler,2011:xi;Guy,2011:19). Between AD 763 and 851, the Tibetan conquests in Central Asia led to the severance of the land and brought a new impetus to sea trade (Gray,1963:9). The ports of China brought ceramic from different origins to serve the Mediterranean, Syrian, Iranian and Iraqi markets via ports in Southeast Asia, Sri-Lanka and India (Stargardt,2014:37). If the Belitung shipwreck was a part of the trade with Başra then it is not difficult to imagine, bearing in mind glass cargoes of Intan and Cirebon shipwrecks, that the increase in glass production in Syria, Iran and Iraq led to the use of maritime routes to serve the elite coastal sites in Southeast and East Asia (Stargardt,2014:37).



Figure 3.2.3.1: *Dusun type jar recovered in the Belitung wreck (Alain,2015:5).*

The 9th and 10th centuries AD were characterised by a growing demand for ceramic and glass between Tang China and ´Abbāsid Iraq, resulting in a massive increase in trade (Sackler,2011:xi; Stargardt,2014:35). New technological refinements and inventions, included the transmission of natron glass to plant-ash glass, changes in glass furnace technology, changes in the structure and size of South China's ceramic kilns, improvements in firing, atmosphere and temperature. These changes, increased the quantity and quality of the production (Sackler,2011:xi;Stargardt,2014: 37,44). Those changes brought a new type of trade (Stargardt,2014:37). The cities of Chang'an and Baghdad were now linked via inland and maritime routes despite the dangers of the vast oceans (Sackler,2011:xi). The increase of the Arab trade forced thousands of Persians and Arabs to migrate, especially in the capital Chang'an (Gungwu,2011:4). When Chang'an was no longer the economic centre of the late Tang dynasty, the coastal port Yangzhou, an important entrepôt to the southeast and Guangzhou further south, became important ports for international



Figure 3.2.3.2: *Chinese Changsha ceramics in a variety of forms from Belitung wreck (http://www.maritime-explorations.com/belitung.htm).*

maritime trade (Gungwu,2011:4). Yangzhou, in the southeast near the coast and, located at a key marketplace at the confluence of the Great Canal and the Yangzi River, was the most important entrepôt for cargoes, such as ceramic and other precious objects, from the north-south communication within the country. The cargoes, were overloaded for sea journeys that took months to reach the ´Abbāsid Empire (Gungwu,2011:10;Stargardt,2014:38;Wood,Priestman, 2016:50). But also precious objects from the ´Abbāsid Empire, such as glass, had been transported to the ports Yangzhou and Guangzhou, as the archaeological excavations show (An, 1991:5). In contradistinction with the literary records that suggest that large amounts of glass were traded from the maritime route after the 11th century AD, the new discoveries show that glass was traded earlier from the maritime route (An,1991:5;An,2010:182).Whether those glasses come from the port of Sīrāf is impossible know. Nevertheless, it is well known that Arab dhows with cargoes transported to Sīrāf to reach as far as the ports of Yangzhou and Guangzhou (Wood, Priestman,2016:48).

3.2.4 Yangzhou and Guangzhou

The earliest reference to the transoceanic voyages from the Gulf to Guangzhou (old Canton, Arabic Kanfu) according to Hourani (1991), came from a Chinese traveller I-Ching, who voyaged in AD 671 from China to Sumatra to meet the owner of a Po-sse (Persian) ship to embark to the south and finally embarked from the coast of Kwang-chou (Guangzhou) to Bhoga (Palembang) (Hourani,1991:62;Flecker,2001:351;Guy,2011:19). Mas'udi in AD 956 (1811-77) provides a clear indication for direct trade between Sīrāf and Baṣra and Guangzhou before AD 877-878, stating that ships from Baṣra, Sīrāf, Oman, India, the islands of Zabaj and Sanf came to Kanfu (Flecker,2001:350). Considerable numbers of Po-ssi (Persians) and Ta-shih (Arabs) lived in Yangzhou and Guangzhou, a fact that underscores the central role of the Persian Gulf merchants at that exchange (Flecker,2001:350;Gungwu,2011:10). The 'History of T'ang' attributes the sacking of Guangzhou to Ta-shih and Po-sse in AD 758 (Hourani,1991:63;Flecker,2001:350). In AD 760, Yangzhou was sacked by Chinese rebels and hundreds of Po-ssi and Ta-shih merchants were killed (Flecker,2001:350).

In the Chinese historical literature 'Zinzhi Tongjian', there is a story of a large imported glass dish (about 27 cm) of great worth offered to the Emperor Daizong by the General Liu Sigong, who ended a rebellion in Guangzhou, and another one larger glass (about 30 cm) offered by the same General to the Prime Minister Yan Zai (An,2009:392;An,2010:177). In AD 775 the General Liu Sigong who ended the rebellion in Guangzhou confiscated thousands of possessions belonging to the merchants. Among them must have been the above mentioned larger glass vessels and glasswares coming from the Islamic world through the marine route (An,2009:392;An,2010:177). The result of the sack of Guangzhou was a prohibition of foreign merchants to the city for a long time, until 792 (Hourani,1991:66). In AD 829, the Emperor guaranteed the safety of the foreign merchants but only for a short period until AD 879 when the rebel Huang Chao in Guangzhou reportedly killed 120, 000 foreign merchants (Flecker,2001:350;Gungwu,2011:10). Guangzhou was no longer a safe place for Persian and Arab merchants.

So far in the discussion above, it was clear from the literary record that Islamic glasswares were considered to be of high-status among the coastal elite at the port Guangzhou (An,2010:177). It was therefore quite likely that early Islamic glass could be found at the port coming from the Sea

Silk Road. The social standing of the ´Abbāsid glass at the port was verified by the recent discovery of glass fragments at the Nanyue King's palace and at the tomb of the Emperor Liu Yan (An, 2010:177). The archaeological excavations in 2000 at the Tang layer of Nanyue King's Palace brought to light glassware, beads and a glass cup having parallels to Nishapur cups. The similarity with the Nishapur cups led the researchers to chemically analyse the find (An,2010:177). The cylindrical cup with the vertical walls was clear yellow with a green tinge (An 2010:177). The analysis shows that the glass was soda-lime, probably coming from the Islamic world (An,2010:177). Later, the archaeological excavations in 2003, 15 km southeast of the Guangzhou city, revealed hundreds of glasswares at the Kang Mausoleum in a crypt of a tomb that dated to 942 AD (15th Dayou reign) of the Emperor Liu Yan, who set up the kingdom Nanhan (An,2009: 388). During the year of his reign, the kingdom prospered and a great demand for luxury goods was observed (An,2010:178). According to Wang, the Arab merchants played an important role in trade and became the middlemen of the Nanhai (Flecker,2001:350;Guy, 2011:22). Hundreds of colourless and transparent greenish fragments of bowls, cups, bottles and so on with some blue fragments were revealed at the tomb, located at the southern foot of Daxiang Hill (2009:389;An,2010:180). Since the tomb had been robbed many times, all glasses were fragmentary with the exception of one bottle that has been successfully restored (An,2009:389;An,2010:181).

The mould-blown decorated bottle with the ten ribs from bottom to neck had parallels to Sasanian and early Islamic glass vessels (An,2009:390;An,2010:181). The neck of the bottle was short, the body was round and the base was convex bearing tube-blowing marks (An,2009:389). Mould blown decoration with outside ridges appears on the bottle which is 5.4cm in diameter, which was discovered in the Grand Mosque in Sīrāf (An,2009:391). This type of pattern dated back to the Sasanian and post-Sasanian period (7th and 8th centuries AD), and fragments with that decoration are in the collection of the Kuwait National Museum and Corning Museum of Glass (An,2009:391). The assemblage of the glassware, with the Islamic technology and the style of emblazonry, led the researchers to chemically analyse ten glasses and the bottle (An, 2010:181). The results show that the glasses were soda-lime, very close similar to early Islamic glass (An,2010:181). While it remains quite uncertain whether the glasswares came from Sīrāf, a port with intense connections to Kanfu, one can hardly fail to see a connection with the Sea Silk route in a period when the Sea Silk route was flourishing. The investigation of the sources provides information about the sea road where the glasses come from. The tomb is dated to AD 942, a period when, according to al-Masudi (1811-77), ships from Sīrāf and Oman met in Kalah Bār, Malaya, the ships coming from China until the year AD 947 (Hourani,1991:75).

3.2.5 Southeast Asia ports

With the Tang China no longer able to guarantee safety, glassware must have been obtained at the intermediate ports of Kalah, as reported by the geographers and navigators in Sri-Lanka (Gungwu,2011:12). The Southeast Asia ports, such as Laem Pho and Ko Kho Khao on Thailand, and Mantai on Sri Lanka, provide us with a variety of glass finds dating back to the 9th and 10th centuries (An,1991:5;Carboni,2001:54;Brabänder,2010:144). For centuries, it was known in the literary sources that goods from the Persian Gulf were obtained from China through that road (Gungwu,2011:12). Three sea roads could be used if glass was traded from Sīrāf and Baṣra ports to China. In 1991, a serious attempt was made by Hourani to describe in detail the routes to China, on a whole journey that includes six months or more of sailing, with stops (Hourani,1991:74). The journey was determined by the direction of the monsoon winds (Hourani,1991:74). Ships from Sīrāf could sail down the coast of Oman in September or October using the northeastern monsoon winds (Hourani,1991:74). Once reaching the ports of Ṣuḥār or Masqat, ships could then cross to Kūlam Malī, (Malabar) (Hourani,1991:71). However, ships would wait there trading until the end of December (Hourani,1991:71). At the end of December, when cyclones came to an end in the Bay of Bengal and the sea was gentler, captains sailed to Kalah Bār (Hourani,1991:74). This journey would last until January.

After a few weeks spent in Kalah Bār, the voyage could start again straight to the Malacca Strait using the northeastern monsoon (Hourani,1991:74). From the Malacca Strait, when the sea turned light and the typhoons were sparse it , was the right period using the southern monsoon for the vessels to sail to the Sea of China (Hourani,1991:74). The second route sailing from the Persian Gulf to China used the coast to head to Kūlam Malī, leaving behind the ports of al Sind, old Hurmuz, Tīz in Makrān, al-Daybul, and al-Manṣūrah, but this route was dangerous because of the pirates (Hourani,1991:71;Flecker,2001:351). Captains from Kūlam Malī could visit Sarandīb and then sail straight to China. A third route involved vessels from Sarandīb to follow the coast of the Bay of Bengal (Hourani,1991:71). In Kalah Bār, vessels spent time there before sailing to Malacca Strait and then to the ports of Sanf, the Champa kingdom and Ṣanf Fūlāw. From there ships could sail to Khānfu, finishing the voyage in the summer (Flecker,2001:351).

Focusing more on the glass trade, Middle Eastern glasswares could come with cargoes possibly sailing from Kūlam Malī to Sarandīb, more specifically to Mantai or Anuradhapura, and then sail straight to China.

3.2.6 Mantai

Mantai in northern Sri Lanka was a principal port during the 9th century AD (Carboni,2001:52;Guy,2011:26;Dhanmanonda *et al.*,2012:3;Guy,2011:26). The port, near Jaffina, was located in a strategic location acting as an agent serving vessels that sailed from the Arab worlds to China (Guy,2011:26). In the literary sources, there was evidence of seagoing vessels from Persia, India, Kunlun and other places sailing from Hainan to Kanfu (Flecker, 2001:352). Jianzhen, a Chinese monk, noted countless vessels on his way from Hainan to Kanfu (Flecker,2001:352). Another reference comes from a Tang Dynasty text, which mentioned that Sri Lanka's vessels were the largest of the foreign ships (Guy,1990:2). The Islamic glassware, pearls, spices and precious and semi-precious stones were carried on vessels that could continue to China (Flecker,2001:352).

The archaeological record strongly suggests that precious cargoes from the Persian Gulf, such as a wide variety of quality pearls and high-quality glassware, were transported to Mantai intentionally to be transferred to further remote areas (Carboni,2001:54;Guy,2011:26). Particularly interesting are the lustre painted cups with the pinched feet that were found during the excavations (Carboni,2001:54). It has already been stated that lustre painted glass was mainly produced in Egypt and Syria and later in other places in the Islamic world (Carboni,2001:52). Nevertheless, the lustre painted cups with the pinched feet found in Sri Lanka seem to have been produced in Mesopotamian and Iranian regions (Carboni,2001:54). The pinched feet with the tiny knobs were a characteristic feature of glass produced in Mesopotamia and Iranian regions in the Sasanian period (Carboni,2001:54). The decoration of a circular pattern and a sort of crown close to the base offers more stability to the vessels (Carboni,2001:54). Similar fragments to the Islamic glass from Mantai have been excavated at Tell Mahuz and Seleucia in Iraq, and in Gilan, Iran, dated to the Sasanian period (Carboni,2001:54).

3.2.7 Khao Sam Kaeo and Laem Pho

Numerous glassware associated with kilns in the Arab world have been uncovered at the ports Khao Sam Kaeo and Laem Pho, situated at Malay Peninsula (***Figure, 3.2.7.1***, An,1991:5; Shindo,2003:177;Dhanmanonda *et al.*,2012:2). The archaeological finds strongly suggest that the sites must have been the main entrêpots during the 9th century AD acting as agents, serving the foreign traders that carried cargoes, such as Middle Eastern glazed ceramics with overglazed lustre painting, characteristically decorated (lustre painted or enameled) Islamic glasses and Chinese ceramics, especially from Changsha kilns (Dhanmanonda *et al.*,2012:2). The archaeological site Laem Pho in Surat Thani, southern province of Thailand, was a flourishing international port and especially important in the connections between China and the Middle East (Dhanmanonda *et al.*,2012:2). Located on the river, Yai Phum Riang offered a secure anchorage for ships that carried luxury items (Dhanmanonda *et al.*,2012:2). From the several systematic excavations that took place from the early 1980s, the most interesting for our research were the excavations conducted in 1988 and 1989 (Dhanmanonda *et al.*,2012:2). Middle Eastern glasses, mostly undecorated or decorated with lustre paint or enamel intimately related to lustre pottery, were unearthed together with the finest Islamic pottery from the 9th century AD: yellow enamelled lustre white ware, blue-green glazed ware, opaque white glazed ware, opaque white glazed with coloured splash, and lead splashed ware (Dhanmanonda *et al.*,2012:2). The undecorated glasswares were mostly transparent with a blue and green tinge (Dhanmanonda *et al.*,2012:2). The decorated lustre painting or enamelled glass was produced by painting the glass with pigment containing silver or copper in a firing temperature in the furnace between 500 °C and 600 °C (Dhanmanonda *et al.*,2012:5). The pigments were absorbed beneath the glass's surface, resulting in colouring the glass permanently with a strong amber and brown colour (Carboni,2001:51;Dhanmanonda *et al.*,2012:5).

The place of origin of the lustre painted or enamelled Middle Eastern glasswares uncovered at Laem Pho is a much-debated subject (Kröger,1995:114;Carboni,2001:51;Dhanmanonda *et al.*, 2012:5). Lustre painted on glass seems to have been produced in Egypt (during the second half of the 8th century AD) and Syria, and then to have been spread rapidly through the Islamic world (Kröger,1991:114;Carboni,2001:51;Shindo,2003:174;Dhanmanonda *et al.*,2012:3). During the 9th century AD, large quantities of those glasses have been unearthed at the ´Abbāsid capital, Sāmarrā, that look different from those attributed to Egypt where they were supposed

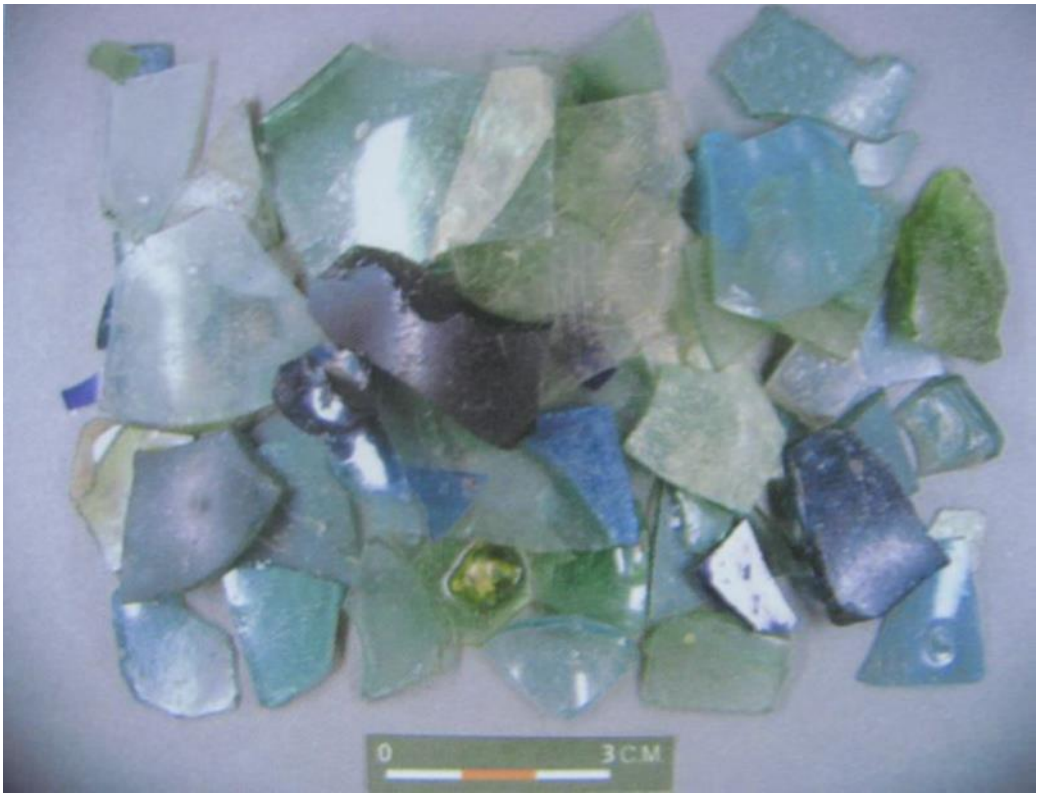


Figure 3.2.7.1: *Transparent blue and green glassware at the historic site Laem Pho (Dhanmanonda et al.,2012:2).*

produced (Carboni,2001:51;Kröger,1991:115). In 2012, Dhanmanonda *et al.* (Dhanmanonda *et al.*,2012:3) analysed the look-alike enamelled glass fragments to establish the cultural relations of the glass. Particularly, the results verify the initial thought that the glass was plant-ash glass with a high magnesium content, produced between the 8th and 14th centuries AD in the Islamic world Similar types of ceramic have been uncovered at the port of Sīrāf, Mantai and Anuradhapura in Sri Lanka (Carboni,2001:52;Dhanmanonda *et al.*,2012:3). Both the ceramic finds found at Laem Pho having parallels with those found in Sīrāf. The similarities between the glassware from the Islamic world with glassware from Sāmarrā, Egypt and Syria show the extent of international exchange between the two worlds. The glass vessels could sail from the most active ports between the 9th and 10th centuries. Lustre glass could load on a ship from Raya port city, where hundreds of polychrome and monochrome lustre-stained glasses were uncovered or from Sīrāf, the most active port in the Persian Gulf until AD 977 (Shindo,2003:177). But the glass departure cannot be determined with sufficient confidence and its route is still open to question. Already toward the end of the 10th and 11th centuries AD Laem Pho because of the attacks by Rajnedra Chola and stop to play an important role at international trade (Dhanmanonda *et al.*,2012:2).

While the archaeological records strongly suggesting that Laem Pho and Ko Kho Khao were main entrepots, new arguments followed. The scholar Bronson (Bronson,1996) strongly disagrees with the view underlying that cargoes were shipped up the Malacca Straight (Flecker, 2001:350). According to his point of view, at least until the 9th century AD cargoes must have been transported overland across the isthmus (Flecker,2001:350). While much work remains to be done in the archaeological field proving the use of the Sea Silk route, glasswares from trading vessels lost in the Java Sea, palpably demonstrate the far-reaching trade between the West and the East (***Figure 3.2.7.2***, Liebner,2014:v). The artifacts recovering recovered from the shipwrecks provide evidence of a diversity of decorative and non-decorative glassware that were transported using the marine route. Based on the glass findings in shipwrecks and the cargo capacities that vessels could carry, the loss of valuable information in the deep waters of the oceans is apparent. Sunken ships packed with archaeological information, however, are difficult to discover but the coast of Southeast Asia and China can provide valuable information in that regard.



Figure 3.2.7.2: *Early Islamic glassware from Cirebon, a 10th century trading vessel lost in Java sea (Liebner,2014).*

3.3 Possible destinations of glass from the Persian Gulf on Africa

The advent of Islam (AD 622), the rise of the powerful dynasty the Umayyad Caliphate (660-749 AD) and later the rise of the ´Abbāsid dynasty at Baghdad all encouraged maritime trade between the Persian Gulf, eastern Arabia and the East African coast (Swahili coast) (Whitehouse,1979;Sheriff,2009:174;Perkins,2015:1). The Muslim desire for natural products, such as timber, slave, ivory, ambergris, gold, and teak, that were plentiful in the East African interior, led to exchange and trade, especially by the 8th and 9th centuries AD. The inhabitants of a narrow African coastal zone exchanged a range of products, of which pottery and glass are the most visible archaeologically (Ricks,1970:343;Horton1996:412;Sheriff,2009:174; Whitcomb,2009:163;Keller,2010:75;Blair,2016:334). Numerous specimens of glass vessels were excavated: a total of 1573 fragments at Shanga (Horton,1996:311;Blair,2016:338), 1700 at Manda (Morrison,1984:227;Blair,2016:339), and a total of 3625 fragments at Unguja Ukuu (Blair,2016:331). Other fragments have been reported at Kilwa, Chibuene (Wood *et al.*,2012), Sofala, Kush (Keller,2010:75;Blair,2016:336), and elsewhere in the western Indian Ocean (Blair,2016:333). It is especially interesting that very little Islamic glass found its way inland (Blair,2016:333). Generally speaking, the theory was that glass was brought from the Islamic lands. Nowadays there is strong evidence, coming from the chemical analysis results of the current research, that significant quantities of Islamic glasses, might actually have entered Unguja Ukuu on the Swahili coast through the ports of Baṣra or Sīrāf via the maritime route before the 9th century AD. In 2016, Andrew Blair was able to build an entire thesis around glass from Kuwaiti and Unguja Ukuu sites, supporting this suggestion (Blair,2016:351). The investigation of the current subchapter will, therefore, present the recent available information about the glass vessels excavated on the east African coast, dated from the 7th until the 11th centuries AD, that might have been exported from Baṣra or Sīrāf's ports.

Whatever the value of the archaeological excavations or the chemical analysis results, questions related to glass trade from the Persian Gulf ports are yet to be properly resolved. Thus, a number of theories are advanced and investigated here, and a number of hypotheses are stated or tested. Problems arise not only due to the lack of literary sources and studies of glass (glass is overshadowed by pottery), but mainly because the systematic analyses of glass objects from Islamic lands is bound to raise additional problems. Here, no recorded information about glass (as a trade or exchange product) exists. Nevertheless, the archaeological occurrence of Islamic

glass on the East African coast is an indication of exchange or trade. During the 7th century AD, with the rise of Islam, the ancient trade route between the Persian Gulf, Eastern Arabia and the East African coast was revived, with the aid of the Near East's skilled people (the ethnicity of the merchants still remains challenging to identify) (Ricks,1970:343;Saitowitz,1996:58; Seland,2014: 375). The Muslim conquest did not eradicate the people of the Persian and Arabian Peninsula, nor the Iranians who dominated the sea-routes from the Sasanian period and sailed with vessels from Baṣra and Sīrāf's ports to the land of Zanj on the East African coast to exchange pearls, cloth, dates and purple dye with sandalwood and ivory (Ricks,1970: 342;Sheriff, 2009:164,174; Seland,2014:384). One is therefore forced to assume that part of the unearthed glass was handled by the above merchants (Saitowitz,1996: 53;Blair,2016: 351).

Through expansion of the Islamic enterprise and trading networks, merchants from the Persian Gulf became very adventurous. Utilising the seasonal cycle of the monsoon winds, they could sail southward as far as Sofala, using knowledge of the inlets and islands, to distribute, among other products, glass vessels and beads (Saitowitz,1996:11,35,51,58;Blair,2016: 352). Merchants from the Persian Gulf were assisted tremendously by the location of the Gulf itself. Even centuries before the advent of Islam, important ports that had access to the hinterland production, did not lose their role as centres of trade. On the contrary, with the rise of the ΄Abbāsid s in AD 750, those ports were strengthened even more (Ricks,1970:343). Here, at the ports of Baṣra, Uballah and Sīrāf, glass could be loaded onto deep-draft ships that stopped there to unload and distribute goods along the river and sea (Ricks,1970:343;Hourani,1995:64; Saitowitz,1996:58). Caliph al-Mansūr, taking into consideration the strategic location of the Persian Gulf ports and the great importance of trade through the river and sea, founded the ΄Abbāsid capital Baghdad near Tigris River and close to those ports with economic advantages (Sheriff,2009:174;Raby,2011:xii). The foundation of Baghdad and the rise of Baṣra and Sāmarrā as luxury production and consumption centres, enhanced the attraction of the Persian Gulf glass trade (Gray,1963:14;Hourani,1995:64;Liu,2010:98). It was at that time that ceramic and glass vessels, as a symbol of wealth, were loaded onto deep-draft ships be transported to the East African coast (Ricks,1970:343;Hourani,1995:64;Sheriff,2009:166). Nowadays, following surveys of the uses of Islamic glass, it can be stated that coastal substantial communities along the Swahili and East African coast, who developed their maritime outlook, wanted to incorporate glass from the powerful ΄Abbāsid dynasty into their material lives (Horton,1996:407;Saitowitz,1996:53; Horton,2004:64;Blair,2016:334). As a socially embedded commodity, having a symbolic meaning related to the prestige and status of the trading class, glass coming from the Islamic lands

was used to structure the cosmopolitan status of the African coastal communities with the aim of drawing visiting merchants closer (Horton,2004:64;Fleisher *et al.*,2015:102;Blair,2016:334). It seems that glass was also used to distinguish the coastal communities from many indigenous coastal and hinterland communities; this was one way to legitimise the exploitation of other African people as slave labourers (Saitowitz,1996:58;Horton,2004:64;Fleisher *et al.*,2015:102; Blair,2016:334). Having a symbolic meaning to represent the prestige of a social class, glass was widely distributed. But what were the political and socio-economic conditions that supported such a wide distribution?

To move glass from various parts of the Islamic world overland or in ships to reach the East African coast, as far as Chibuene, required stable political and socio-economic conditions, unity supported by a dominant religion, common language and politics, safety and stability (Saitowitz, 1996:11,12,35,58;Whitcomb,2009:166). Greater stability observed with the ´Abbāsid dynasty. A century earlier there was obvious continued tribal and political instability (Ricks,1970:343). Baṣra was one of the witnesses to a number of violent upheavals (Mason,Kealle,1991:53; Saitowitz,1996:53). In the year 868 AD, the port was taken with the uprising of the Zanj slaves (Ricks,1970:351; Mason,Kealle,1991:53;Saitowitz,1996:53). This daring act of the Zanj revolt and the subsequent sacking of Baṣra may have affected its fortune as a trade centre, by disrupting normal shipment of goods between AD 868 and 883 (Saitowitz,1996:53). Later, the port witnessed another violent event known as the Qarmatian sack, which lasted 17 days (Mason, Kealle,1991:53). From about the latter half of the 9th century AD, the ports of Baṣra and Uballah declined, replaced gradually by Sīrāf, which traded directly with China and became an essential link in trade, as far as Zanzibar, Sofala and Madagascar (Ricks,1970:344-345,350; Mason, Kealle, 1991:53;Saitowitz,1996:48,53). During this period, the Shatt-al 'Arab River had silted up considerably, preventing deep-draft vessels from navigating the river and reaching Baṣra and Uballah (Ricks,1970:344).

In AD 906, we come upon a vacuum in Persian Gulf trade, with the demise of the Tang dynasty in China and the Fatimid conquest of Tunisia (Saitowitz,1996:53). Here, the assumption is that the shift of power to the caliphate in Egypt in AD 969 resulted in the shift of the trade route to the Red Sea and the Mediterranean regions (Whitehouse,1979:867;Saitowitz,1996:59). In fact, when the Fatimids took control of trade, many of the early Islamic emporia were supplemented by new ports. Among those emporia was Sīrāf, that was later severely damaged by an earthquake in AD 977 (Ricks,1970:351;Whitehouse,1979:867;Saitowitz,1996:59). The following section is devoted to the famous port of Sīrāf on the Iranian coast, as it occupies a special position among

the Persian Gulf ports for its extensive trade with Swahili and the East African coast (Ricks,1970: 344;Whitehouse,1979:868;Hourani,1995: 67;Whitcomb,2009: 72;Sheriff,2009:174).

Through the work of geographers and scholars, Sīrāf provides us with a panoramic view of trade (Whitehouse,1979:868;Sheriff,2009:174). In AD 947, the medieval geographer al- Mas'udi (1861-77), cited in Ricks (Ricks,1979), in his work Muruj al-Dhahab wa Ma'adin al Jawhar, noted that traders made voyages from Sīrāf to India, to the Maldive islands, to the sea of Zangibar (bahr al-Zanj) and could sail southward as far as Sofala (Ricks,1979:350;Hourani,1995: 67;Saitowitz,1996:59;Whitcomb,2009:174). The above story was a personal experience of the geographer, who sailed in in a trading vessel to the land of Zanj (Hourani,1995:67;Saitowitz,1996:59;Whitcomb,2009:174) Later, in AD 956, al- Mas'udi (1861-77), cited in Ricks (Ricks,1979), describes the direct 'open-sea' route from the Persian Gulf taken by the adventurous Sīrāfi captains this route was destined for the port Island of Qanbalu (Zanzibar) and was the shorter but most dangerous and advantageous route (Ricks,1979:35). In the wide gamut of information provided by al- Mas'udi (political and military organization of Zanj, language, religious practices, mixed populations of Muslim and Zanj indigenous we are fortunate to know which products were unloaded at Sīrāf, such as spices, cotton cloth, perfumes and kitchenware, to be exchanged with ambergris, leopard skins (from a site on the island of Pemba in the Zanzibar), gold (from the land of Sofala), ivory and slaves (Ricks,1979:351,Whitcomb,2009:174). Whether glass was among the kitchenware, there is no such a reference. Beyond al- Mas'udi's information about trade commodities from the Persian Gulf ports, Ibn Hawqal (1086), cited in Ricks (Ricks,1979:351), reported in AD 961 that he met a very wealthy Sīrāfi merchant by the name of Ahmad ibn 'Umar al-Sīrāfi in Baṣra, whose ships carried spices, precious stones and perfumes to the East African littoral, particularly at Zanzibar Baṣra was the most important port, especially before the 9th century AD, for the trade with Swahili and the East African coast, although we unfortunately do not have any references. The most illustrious writer and philosopher in Iraq, by the name of Abu Uthman Amr b. Bahr al-Jahiz (AD 767–868) (1997), cited in Whitcomb (Whitcomb,2009:174) had an encyclopaedic knowledge and, provided detailed information about the large slave population, the Zanj, that inhabited the outskirts of Baṣra in the 9th century AD. He indirectly mentions slave trade as his family may have been a trade product from the African coast (Whitcomb,2009:174). In addition to Bahr al-Jahiz, an unknown Chinese scholar of the 9th century AD reported that Iranian traders with great capabilities dominated the sea routes (Sheriff,2009:174). The geographer Abu Ishaq al-Istakhri (1927), cited in Wilson (Wilson,1927:247), writing in 950 AD, offers clues to the Sīrāf

trade with Zanzibar. Providing the fullest account of Sīrāf, he stated that the city houses were constructed by teak wood (saj), or other wood (from the country of Zanj, savahil-I zangibar; zangibar) and the inhabitants, spending huge sums (30,000 dinars), take such an excessive pride in the elegance of their houses (Ricks,1970:346;Whitehouse,1979:869;Whitcomb,2009:174). Supporting this body of material, we have stories of captains, merchants and travellers, which are equally valuable (Ricks,1970:344;Whitehouse,1979:868;Hourani, 1995:67;Whitcomb,2009:72;Sheriff, 2009:174). As an example, the story of Abu-Zayd al-Ḥasan ibn-al-Yazīd (AD 877-915) (1845), a merchant from Sīrāf, cited in Hourani (Hourani,1995:68), tells us that in AD 916 Sīrāfi merchants visited the Zanzibar coast. Other stories are mentioned by the Iranian sea captain Buzurg ibn-Shahriyār of Ramhurmuz (1966), cited in Hourani (Hourani,1995:68) in the book Kitāb 'Ajā'ib al-Hind (Wonders of India), which provides tales of life and adventures from sea captains and merchants travelling from Sīrāf, al-Baṣrah and 'Umān to India, the Far East and East Africa (Whitcomb,2009:174). In AD 922, the captain described a slaving adventure to Sofala (on the Mozambique coast), writing that a Sīrāfi captain traded 200 slaves and tried to maximize his profit by kidnapping the local ruler to sell him as a slave in Oman (Whitcomb,2009:174).

So far in the discussion, it has been obvious that if we solely relied upon the occasional notes of the geographers, travelers and scholars listed above, much of the glass trade from the Persian Gulf to Zanzibar would be invisible. If glass, as a trade item, in Zanzibar failed to impress, this was, however, not due to its low value – as attested by the recovery of uniquely coloured pieces of blue, red, and mosaic decorative vessels - but chiefly to the main interest of geographers at locations, sea routes and connections (Blair,2016:300). This was not the only time that glass failed to be appreciated; in the first half of the 20th century, the British colonial administrator F.B. Pearce (Pearce,1920:396), cited in LaViolette (LaViolette,2004:135), writing about archaeological ruins at Zanzibar, noted the presence of numerous fragments of Arabian and Syrian glass found together with some beads and pieces of glazed and coloured pottery. The obvious significance of Zanzibar as a trade emporium with the wider Indian Ocean in the late 1st millennium AD, was still not recognised (LaViolette, 2004:135;Blair,2016:250).

3.3.1 Unguja Ukuu, Zanzibar

Unguja Ukuu was clearly a site with huge potential for further research. Academic attention to the site came only later (from 1960s and onward) with the surveys of Neville Chittick (Chittick,1965) and later Mark Horton and Cathy Clark (Horton,Clark,1985). The geographical position of Unguja Ukuu, located on the largest island in the Zanzibar archipelago and near to the Tanzanian mainland, was a gateway to the East African mainland, to the west Indian Ocean, to Arabia and the Persian Gulf (Blair,2016:248). Here, East African commodities from the mainland could have been exchanged in return for commodities from the Persian Gulf. Although, it was not recorded in the historical literary records, it is now visible in the increased archaeological research that glass from the Islamic lands was coming to the vibrant trading emporium Unguja Ukuu, Zanzibar most probably through the sea route (Blair,2016:302). The question readily arise, could glass, dated to the 7th-9th century AD, have travelled from the ports of Başra or Sīrāf? The answer to this question came from the typological analysis conducted by the scholar Andrew Blair, as a part of the archaeological study of the Sealink Project.

In 2011-2012, the Sealink Project, attempting to raise awareness about Unguja Ukuu and its long-distance connections, undertook excavations at the ancient Zanzibari capital (Blair,2016:253). A huge amount of glass fragments, a total of 3625, were removed from six trenches, collected, bagged and transported to the UK for further analysis (Blair,2016:253). Through the excavations it was obvious that glass, datable to the 7th century AD and onward (8th, 9th, 10th century AD), was common in areas associated with structural occupation and less common in areas used for dumping and other non-structural activities toward the foreshore (Blair,2016:287). In brief, the excavations reveal the dominance of the open vessel forms (86.67%), with just 10.98% closed vessels and 2.35% semi-open vessels (Blair,2016:293). Attention should be draw to that dramatic lack of variety; the majority of the open vessels (cups, beakers or bowls) were plain forms with unelaborated simple rims (Blair,2016:294). There were some elaborate variations (stepped, triangular-beaked, inward folded rims) but there were fewer of these (Blair,2016:302). A glance through the appearance of glasses shows that the above types and especially the finer specimens were well known in other areas of the Islamic world. The key to researching the glass trade in Unguja Ukuu probably lies within the commonplace wares scattered along the East African coast and the Persian Gulf and finding the best parallels (a difficult and time-consuming task). Fortunately, Andrew Blair has not ignored the parallels of the Persian Gulf, deciding that the two

Kuwaiti sites and Sīrāf were significant and were not coincidental. In fact, Blair tried to explore the typological attributes, the functional role of glass, as a trade product coming from a long distance; his study proved that the best parallels were concentrated in the Persian Gulf region and that a wide range of glasses from Unguja Ukuu are likely to have begun their seasonal trip in the Persian Gulf region, ultimately at sites like Baṣra and Sīrāf (Blair,2016:342). For reasons that will soon become clear, the fact that glass was traded from the Persian Gulf ports does not necessarily mean it was produced there. In Unguja Ukuu, the presence of finer specimens, although small in number (only 33 fragments were uncovered), can be linked to specific production areas, thus an indication that decorated glass could only be organised and collated there. There is no reason to think that this could happen exclusively with the elaborate types of glass.

Blair writing on the topic proposed an Iraqi or Iranian provenance of a mosaic or millefiori specimen. In fact, its discovery was of great archaeological importance, as a rare piece of an Islamic tradition that remained fashionable for a short period, ending by the 9th-10th century AD (Blair,2016:297). The possibility of Iraqi or Iranian provenance is suggested by the discovery of the floor tiles from the throne of the caliphate residence of Jawsaq al-Khaqani at Samara and a single piece at Nishapur (Blair,2016:147). The absence of a similar fragment at the Kuwaiti sites and its presence further inland might indicate that it was transported from the Persian Gulf ports to be shipped further away. The same possibility may be accepted of the elaborately worked pieces uncovered at Unguja Ukuu bearing trailed, pinched and scratch-engraving decoration (Blair,2016:281). There were further difficulties in identifying the origin of the decorated specimens, especially the three scratch-engraved fragments that were not found at the Kuwaiti assemblages; their standardised geometric and floral patterns (a chevron pattern of triangles within a section of two horizontal and parallels lines) have been identified across a wide area, from Iraq at sites such as Sāmarrā, Tulul al-Ukhaidir and Nippur, Iran at sites such as Nishapur, Susa, Fusṭāṭ , Raya and Levant at Qal'at Seman, Syria at sites such as al-Raqqa and al-Mīna, Nessana, North Africa, West Africa (Gao, Mali) and as far as the in the crypt of the Famen Temple in the Shaanxi Province of China (the dishes were placed in the crypt in AD 874) Blair,2016:148). Hence, it is impossible to say with certainty where the samples found in Unguja Ukuu were made. Whether Baṣra or Sīrāf should be looked at as the possible port of export is less important at the moment.

3.3.2 Pemba

By integrating the new archaeological evidence from Swahili coastal towns and regions and especially Tanzania's three major offshore islands (Unguja, Pemba and Mafia), the significant role of the Persian Gulf trade is highlighted (LaViolette,Fleisher,2009:441,449). It is especially interesting that a rare mosaic or millefiori specimen uncovered at Tumbe, on the north coast of Pemba island, was similar to the piece described above found at Unguja Ukuu (Fleisher, LaViolette,2013:1157;Blair,2016:147). It is speculated that the specific type was imported to Pemba from Iran or Iraq, due to the parallels between the floor tiles from the throne of the caliphate residence of Jawsaq al-Khaqani at Samara and a single piece at Nishapur (Blair,2016: 147). Tumbe sits on Pemba, an island in a strategic location that was a central part of the Swahili heartland, engaged in long-distant trade, with contacts in the African interior, and with an array of peoples in the Persian Gulf region (*Figure3.3.2.1*, LaViolette, Fleisher,1999:63;LaViolette,Fleisher, 2009:441,443,449;LaViolette,Fleisher,2013:1151). Some scholars believe that Pemba was Kanbalu island (also Qanbalu), mentioned by al-Mas'udi (1861-77). During his visit to Kanbalu, he mentioned that a Muslim population and a royal family lived there in AD 916 (LaViolette, Fleisher,2009:433). Mitchell noted that if Pemba is correctly identified, then in around AD 750 the island may have been conquered by Muslims to provide an entrepôt for the slave trade, where slaves must have been obtained mostly from the African mainland to be exported in large numbers for use in plantations and drainage projects in the southern Iraqi marshes (Mitchell,2005:111).

The engagement of Pemba with the Persian Gulf trade from the 7th-10th centuries AD is well attested by the imported pottery from Sīrāf and glass from Iran and Iraq (Fleisher,LaViolette,2015:68;LaViolette,Fleisher,2013:1164). Imported material culture here was crucial in order to distinguish the habitants from the other hinterland people and to structure a cosmopolitan status for merchants coming from distance places (Fleisher *et al.*,2015:110). The archaeological excavations at Tumbe have provided new evidence to broaden the discussion of glass trade from the 7th to the early 10th centuries AD, revealing a remarkable density of 2800 imported glass fragments and a millefiori fragment among Sasanian-Islamic and Sīrāf storage jars (*Figure, 3.3.2.2,* Fleisher,LaViolette,2013:1158). According to typological criteria and shape, 255 were diagnostic rims and body fragments of beakers, bowls, flasks and smaller phials, bearing interesting parallels with glasses uncovered at Shanga and Manda (Fleisher,LaViolette,2013:



Figure 3.3.2.1*: Sasanian-Islamic jar on the floor of an earthen house, Tumbe (Fleisher, LaViolette,2009:443).*

1158). The beakers and bowls made up most of the collections (Fleisher,LaViolette,2013:1158). The glass containers were uncovered on floors and in the fill of two burned houses dating to the 7th-10th centuries AD (LaViolette,Fleisher,2009:433;Fleisher,LaViolette2013:1164). We now turn to an inquiry into the uses of the imported glass; their presence in seemingly humble earthen houses may indicate that they became a commonplace part of daily life or that they had been stored and protected from view as goods of status markers (Fleisher,LaViolette,2013:1164). An intriguing problem connected with the glass imports is their provenance. To deal with it will require chemical analysis results. It is especially interesting that the glass imports were uncovered in the same houses that contained turquoise-blue glazed ceramic jars manufactured in Iraq between the mid-8th -10th centuries AD (LaViolette,Fleisher,2009:441;Priestman,2016:25). The specific type of jar, glazed with a turquoise colour by adding copper under oxidizing

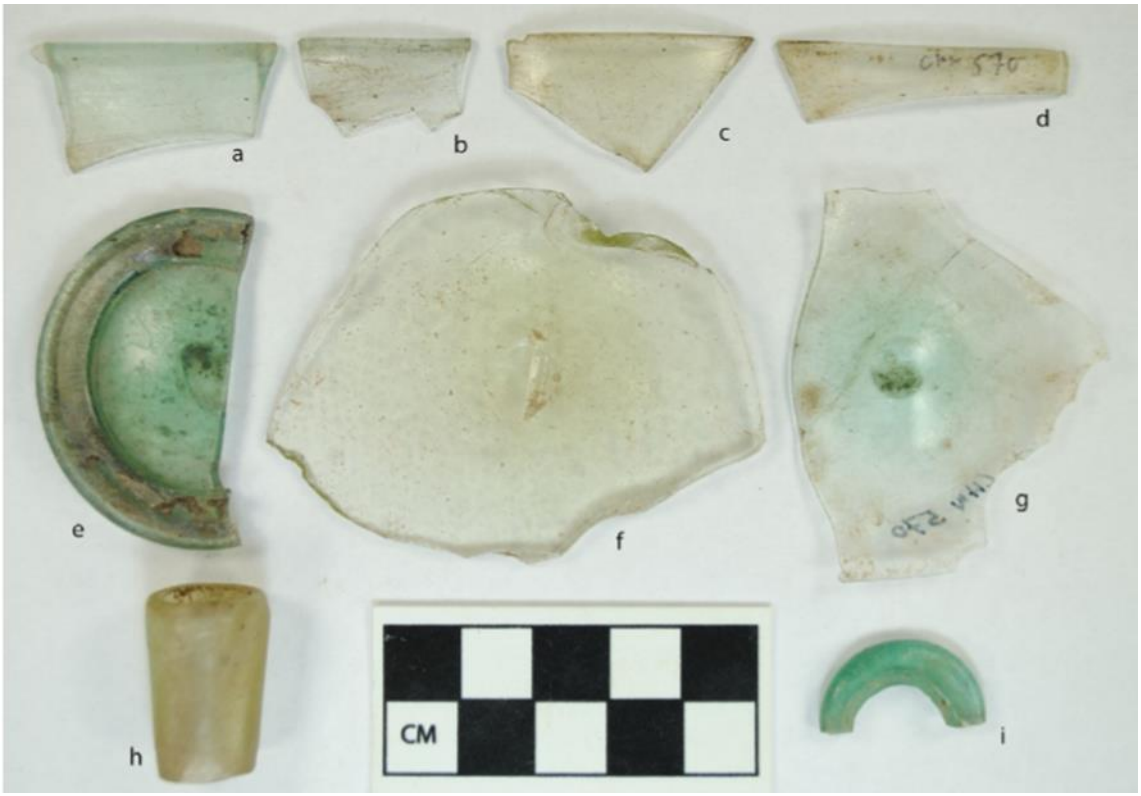


Figure 3.3.2.2: *Beaker rims, bases and phial fragments from Tumbe, Pemba (Fleisher,LaViolette, 2013:1158).*

conditions, is part of a diverse short-lived traditional production (sometime in the 820s) and its major area of production was somewhere in Iraq (Wood,Priestman,2016:52; see subchapter 3.2). The scholars Masson and Keall (Masson, Keall,1991) attributed the jars as originating near to the port-town of Baṣra although there is no existing evidence (such as kilns) for this attribution (Priestam,2016:2;Wood,Priestman,2016:52). Zanzibar develops our awareness of about the widespread use of the Iraqi jars (Priestman,2016:22).

Whether the turquoise jars were products of a direct exchange from Persian Gulf ships sailing from Baṣra or Sīrāf ports to East African ports, or whether they were transported to Pemba from other ports via local distribution networks, is beyond of the scope of the present study (Wood, Priestman,2016:48;Priestman,2016:22). What is important is the fact that the imported small vials and jars could have started their journey from the ports of Baṣra or Sīrāf together with the Sasanian-Islamic and other ceramics from the Persian Gulf. For a number of years, no glasses from Pemba were studied and analysed (Shiu,2017:5). In 2017, Shiu used an electron microprobe to chemically analyse five fragments of Islamic glass that came from Pemba island

(Shiu,2017:80). The site that the fragments came from is unknown, as they were a gift from Major Francis B. Pearce to the Victoria and Albert Museum, but their date is known from the record (medieval date) (Shiu,2017:80). The analysis shows that Iraqi/Iranian glasses were traded as far as Pemba island (Shiu,2017:265). Clearly, the analysis shows a mould-blown glass bearing decoration with a concentric lozenge, an example of a plant ash glass belonging to the low MgO-high Al_2O_3 glasses. For the purposes of the present investigation, it matters that this type was not uncommon in the Iranian region (Kroger,1995:87;Shiu,2017:265). More specifically, the glass was related to the Nishapur coloured glass suggesting that it could have come from Iran. The second important mould-blown fragment decorated with vertical ribs was also a plant ash glass belong to high MgO-low Al_2O_3; the fragment has a very close relationship with glasses from al-Raqqa and Raya. Shiu's suggestion to search for the origin of glass in Iraq seems to be fruitful, as glasses produced in Iraq tend to have high MgO and low Al_2O_3 concentrations (Shiu,2017:266). According to Shiu, the presence of Iranian and Iraqi glasses in Pemba suggest commercial contact between the Persian Gulf ports and the East African coast (Siu,2017:266). But Pemba was not the only island in Tanzania where high quality early Islamic glazed wares from Persia have been found together with small quantities of Islamic glass (Chittick1965:276; Horton,1974:394;Oliver,1975:194;Whitehouse,1979:880,Horton,1986: 203).

By integrating the new archaeological evidence from the African coastal settlements in Kilwa, Manda and Shanga, the significant role of the Persian Gulf at this exchange is underscored (Chittick1965:276;Horton,1974:394;Oliver,1975:194;Whitehouse,1979:880;Horton,1986:203; Horton,1996:311). Between 1960 and 70, Neville Chittick (Chittick,1974:3) undertook the largest surveys, conservations and excavations of his time in tropical Africa (Garlake,1977:302; Posnansky,1978:496;Whitehouse,1979:878). Thanks largely to his work, we now possess archaeological evidence at Manda and at the oldest levels of Kilwa that attests to the presence of early Islamic glass together with imported goods that match with others found in Sīrāf in the Persian Gulf (Horton,1986:203;Oliver1975:194).

3.3.3 Kilwa

From 1960 to 1965, Chittick, as a director of the British Institute in Eastern Africa, dug at the modern day village of Kilwa Kisiwani, south of Dar-es-Salaam, and at the Husuni complex, on the north coast of the island (Chittick,1965:276;Posnansky,1978:496). The Tanzanian site of Kilwa Kisiwani in Period I, no later than the 9th century AD, was an indigenous (according to historical and linguistic evidence) settlement of 'farmers, fishers and traders' with immigrants coming from the Arabian/Persian Gulf, living in houses of mud and wattle, exploiting the local resources, involved in the iron smelting and the manufacture of shell beads (Whitehouse,1979:879;Blair,2016:28). It is especially interesting that Kilwa received a small quantity of durable foreign goods, such as glass and carnelian beads, that arrived from the Persian Gulf or India (Whitehouse,1979:880). The following section offers a resumè of early Islamic glass found there.

Fragments uncovered at Kilwa bear the so-called honeycomb patterns (Goldstein,2005:106). This type of decoration was based on the previous Sasanian models and represents a hallmark of the Iranian glass production from the 8th to 13th centuries AD (Carboni,2001:35). A number of similar moulded fragments with honeycomb patterns were found on the East African coast (Manda and Mafia) and in the Persian/Arabian Gulf (Sīrāf and Qasr-I Abu Nasr, Shiraz), suggesting connections between those places (Goldstein,2005:106). Here, according to the excavator, straight-walled beakers with chambered and rounded rims were also found (9th-12th centuries AD). Such straight-walled undecorated fragments were excavated at Kilwa and Manda (East African coast) dated to the 9th and 11th centuries AD with lots of parallels in the Islamic world (Chittick,1974:395;Goldstein,2005:179). More specifically, a fairly similar fragment with a comparable profile but bearing decoration was excavated at Nishapur, while beakers with honeycomb patterns were found in Egypt and Mesopotamia, in Sabra Mansuriyya, near Qayrawan and in Dvin, Armenia dated to the 9th century AD (Chittick,1974:395; Goldstein,2005:179). It should be mentioned that Chittick recognised the Egyptian origin of an elaborate moral flask bearing honeycomb patterns that was found in Kilwa (Chittick,1974:398; Goldstein,2005:161).

We now come to a type of vessel that was very popular in the central Islamic lands (rather than outside): the globular vessels with folded and flattened rims (Chittick,1974:406; Blair,2016:65). Vessels of this type were excavated at Kilwa, Shanga and Unguja Ukuu along the East African

coast and in the Syro-Palestinian region, such as at Tiberius (650-980 AD), at Jericho (7th -8th century AD), at Kursi (8th century AD) and at Bet Shean. They were also found in Egypt at Fusṭāṭ (late 8th century AD), in Iraq at Seleucia, Sāmarrā and Ctesiphon (insecurely dated), in the Kuwait Bay at Kadhima and Shiqaya and in Iran at Nishapur, Sīrāf and Susa (insecurely dated to 9th-10th centuries AD) (Blair,2016:65). Apart from the above Islamic type vessels, cylindrical bowls with vertical walls, similar to those found in Sāmarrā, Nishapur and Qasr-i Abu Nasr, were excavated at Kilwa and Manda (Goldstein,2005:68). But these, of course, are not the only types found at Kilwa that have also been found across the Islamic lands and on the East African coast; the small bottle with the bulging neck uncovered at Kilwa was widely distributed in the Islamic world, as shown by its presence in Fusṭāṭ , Sīrāf, Nishapur, Seleucia, Kadhima, Shiqaya, Manda, Shanga and Mafia (Blair,2016:82). Finally, we should mention the open vessels with plain rims (rounded) that were identified during Chittick's excavations at Kilwa, which best parallel objects found on the East African coast (Unguja Ukuu and Manda) and in the Persian Gulf (Sīrāf, Kadhima and Shiqaya) (Blair,2016:107-8).

So far in the discussion above, it is clear from the archaeological record that early Islamic glassware entered Kilwa. But which places did the glass come from? Unfortunately, chemical analyses have not yet been undertaken, so there is no information given about the sources. The glass could have originated in Egypt, in the Syro-Palestinian region, in Iran, in Iraq or elsewhere. Although the origin cannot be established with certainty, some glasses could have travelled in the 8th century AD from the Persian or Arabian Gulf, when traders from this area established a route linking East Africa and China. Or glass could also have travelled from the Red Sea, especially after the 9th century AD, when Muslim traders set up a different route linking East Africa and the Mediterranean (Horton,1986:89). Kilwa was in a strategic location on the Swahili coast (located in the southernmost part where ships could be reached from the north with monsoon winds) and the glass could have arrived there either from the northern Swahili coast or from Oman, the Gulf or the Red Sea (Suton,1993: 3;Zhao,2012:49). In fact, it is therefore quite likely that some glass came from the contemporary town of Sīrāf on the Persian Gulf, together with the so-called blue-green glazed Sasanian-Islamic ware (the type of fossils found at Sīrāf and Banbhore) and with the Chinese white glazed pottery recovered there (Oliver,1975:194; Whitehouse,1979:880). From the base of a red deposit, datable back to the 8th century AD, (according to the suggestions of Chittick), tin-glazed Islamic pottery, probably imported from Mesopotamia, and pottery of the 'sgraffiato' type was uncovered (Chittick,1965:284;Oliver,1975: 194;Blair,2016:31). The presence of the Islamic glass, together with scattered pieces of blue-

green glazed 'Sasanian-Islamic' wares that neutron activation analysis shows were made in Iraq, is an indication of exchange relations (rather than developed trade before the 11th century AD) (Posnansky,1978:498). Glass could have been received as an occasional goods item from ships travelling between the Gulf and East Africa, presumably in exchange for commodities (Whitehouse,1979:881). Through a careful reading of the masterly account of Chittick's excavations at the site at Kilwa, one can hardly avoid seeing that it was difficult for Chittick to free himself of the contingencies of this Gulf/Sīrāf connection (Chittick,1965:284;Scanlon,1990:90). In the archaeological record of Neville Chittick, we now possess evidence that Kilwa was not the only place that yielded evidence for this Gulf/Sīrāf connection. More concrete evidence comes from Chittick's excavations (Chittick,1984), assisted by Robert Soper, in 1970 and 1978 at Manda.

3.3.4 Manda

Manda was a prosperous island port just north of Lamu on the Kenyan coast, where its inhabitants were enjoying commodities from China and the Islamic world (Horton,1986:207). There is no doubt that from the time of its foundation, early Islamic unglazed and glazed storage wares (one half consisted of glazed wares of high quality) mostly from Persia, Islamic glass and Chinese greenwares (of the Yue yao kilns) were imported there (Anthony,1975:194; Whitehouse,1979:882;Roberts,1985:621;Horton,1986:201;Scanlon,1990:90). When identified, those imports were not unexpected. There are similarities with pottery and glass found in the contemporary town city at Sīrāf on the Persian Gulf (Anthony,1975:194;Whitehouse,1979:882; Roberts,1985:621;Horton,1986:201;Scanlon,1990:90). In many respects, the imports of high prestige items in such high proportions led to the assumption of foreigners that settled at Manda that in order to establish exchange relationships, it was necessary to present high prestige items to local communities to cultivate the local taste for foreign luxuries (Horton,1986:207). Actually, Chittick's final excavation report claimed that those foreigners were merchants from the Persian/Arabian Gulf who immigrated to this harbour and were involved in the transoceanic African trade (Horton,1986:201;Roberts,1985:621). Chittick's opinion could explain the similarity between the earliest buildings uncovered there and those from the Persian/ Arabian Gulf (Roberts,1985:621;Horton,1986:202;Whitehouse,1979:883). Manda's inhabitants were claimed to be building with brick and stone, a technique foreign to the area but well known in

the Gulf seaports of Sīrāf and Sohar (Horton,1986:202;Whitehouse,1979:883). Here again we find evidence of the connection between Manda and Sīrāf by looking at the Changsha stoneware that was uncovered at pre-Mosque layers in Sīrāf, around AD 850, the earliest known occupation of Manda (Horton,1986:202). Based on the Changsha stoneware, Chittick (Chittick,1984) dated the earliest occupation to around AD 850, even though later Mark Horton (Horton,1986:202-4) was of the opinion that Manda had flourished before AD 836 (Changsha stoneware does not appear in the new capital Sāmarrā in AD 836). It is impossible to say if this is true or not, but the important thing is that those imports were found at layers below white glazed pottery that is dated to the 11th century AD (Horton,1986:203;Whitehouse,1979:882).

The next question significant for the current research is whether glass, as a luxury material exchanged across the Western Indian Ocean, entered Manda through Sīrāf's port. The answer to this question is that there is no evidence. While we have to leave this question unanswered, a number of assumptions can be made. Somewhat unexpectedly, among the large quantities of glass finds that seem to come from the early Islamic world, there are fragments of bowls and flasks that, in many respects, parallel Sīrāf's glass material (Roberts,1985:621;Blair,2016:339). Special mention has to be made of the work of Helen Morrison (Morrison,1984) who studied these glass finds (Roberts,1985:621,Blair,2016:339). After careful examination, Morrison (Morrison,1984) estimated that around 140,000-150,000 glass vessels were imported during Period I (dated to 800-1000 AD) at Manda, with the closest parallels to vessels uncovered at Sīrāf (Roberts,1985:621). Before proceeding to the description of the best parallels, it should be mentioned that certain types of open vessels, bowls and beakers, and closed vessels, flasks and flasklets, were imported in even proportions (Blair,2016:334). A minor problem arises with regards to the plain vessels, as this category has been found in different parts of the Islamic world, so their classification is difficult and will not be presented in this study (Blair,2016:114). The category of open vessels includes undecorated straight-sided beakers with parallels to the cylindrical beakers of Mesopotamian or Iranian origin, located nowadays in the Khalili collection (Goldstein,2005:184). Moreover, these cylindrical beakers with thin, straight walls and a flat base have parallels to the more elaborate pincer-decoration beakers that were found at Sāmarrā, Susa, Nessana, Turang Tepe, Nishapur, Fusṭāṭ and as far as the Famensi pagoda, at Dingxian, and the Hebei province (Goldstein,2005:96).

At Manda's data has possibly identified one of the finest glassware in the early and most important period of Islam, a blue scratch engraved fragment that can be directly associated with large blue plates that were uncovered at the Famen Temple and other fragments uncovered in a variety of

places (Blair,2016:148). Thus, a definite association with a specific place is impossible (Blair, 2016:148). A very similar situation concerned with the category of the shallow cylindrical bowls with vertical walls that were excavated at Manda. In many respects they parallel cylindrical bowls from Sāmarrā, Nishapur, Tall Abu Sarifa and Qasr-i Abu Nasr so their association with a place is again not possible (Goldstein,2005:68). Mention should be made here also at the closed vessels uncovered at Manda. In fact, a complete thick-walled small flack undecorated found at Manda resembles a similar flask from Sīrāf. A small flask slightly different of bell-shaped with a tall base register in arcading from Manda parallels lot of bell-shaped flask decorated in a variety of techniques uncovered at Bujnurd in Khurasan, Tall Abu Sarifa and mould-blown flask from Fusṭāṭ (Goldstein,2005:275). A glance through flasks from Manda shows that mallet-shaped flasks, sometimes refer as carafes, are especially notable at China, Inner Mongolia, Nishapur and Sabra Mansuriyya (Goldstein,20005:186). A colourless frgaments of a small bowl with moulded honeycomb patterns found at Mandas excavations presenting similarities with pattern moulded bowls from Sīrāf and Shiraz (Goldstein,2005:106).

A word finally for the vessels with flaring necks (straight) has close contemporary parallels to Fusṭāṭ , Sīrāf, Tiberius, Seleucia and Nishapur (Blair,2016:81). Eventually, through discoveries of finds, ideas began to change (Blair,2016:70). While Sīrāf was the most active port, between the 9th and 10th century AD, there is no reason to not suggest that glass could loaded on a ship in the Red Sea ports. Although the ceramic evidence suggests contacts with the Persian Gulf the Red Sea should not be discounted. New findings have thrown new questions. Of significant importance for this assumption is a 10th -11th century AD Fatimid coin from Manda suggesting relationship between the Red Sea with the East African coast (Horton,1986:210). In fact, the Fatimids developed trading interest with the Swahili coast; Egyptian workshops were strongly interested in products from the east African coast, such as rock crystals and ivory, products in great demand in Egypt (Horton,1986:210). Whatever the relation between Manda and the Persian Gulf or the Red Sea important is that the excavations at Manda offer the opportunity to estimate glass East African trade (Blair,2016:338).

3.3.5 Shanga

Among East African sites that are key to providing an understanding of the development of the East African glass trade/exchange with the Persian Gulf in the first millenium AD is Shanga, where 1537 fragments (most of them seem to be in the form of basic beakers and bowls of a similar size) were excavated from an area of 476 m^2 (Blair,2016:338). As Manda, Shanga was a typical Swahili site on Pate Island off the coast of Kenya that was also extensively (five digging seasons) excavated from 1980 and onward under the auspices of the British Institute in Eastern Africa by Mark Horton (Horton,1987:88). Horton's excavations revealed 25 phases of occupation from the 8th through the 14th centuries AD (Horton,1987:90). Shanga was a small indigenous fishing village, established in the second half of the 8th century AD, that was developed rapidly (indication of the wealth and the power of the site was the enclosure wall and stone buildings) through the engaged in trade with the Persian Gulf (Horton,1987:90;Blair, 2016: 31). Here, early wood mosques show the existence of a small percentage of Muslim, probably a Muslim elite, as early as the 9th century AD (Horton,1987:90;Allibert,1996:479). Horton draw a picture of Islamization presenting imports of pottery and glass that were made in the Arab and the Persian world (Allibert,1996:480). There can be little doubt that there is a lack of detail in Hortons publication of glass, giving only a brief insight, but even though there are some information about the beakers, bowls, goblets, globular vessels found there (Blair,2016:338). Though the descriptions are very meager we are informed of the occurrence in Shanga of a very common type within the central Islamic lands the globular vessels with the folded and flattened rims. Typological analysis conducted by Andrew Blair clearly show that this type of folded and flattened rims uncovered at Shanga has parallels to many varieties of globular vessels uncovered in the Syro-Palestinian region (Tiberius, Jericho, Bet Shean), in Egypt (Fusṭāṭ), in Iraq (Seleucia, Sāmarrā, Ctesiphon) and in Iran (Sīrāf, Susa, Nishapur) (Blair,2016:82).

By integrating the archaeological evidence here at Shanga can be found a widely distributed type the bottle with the bulging neck. Blair was inclined to see the best parallels at Fusṭāṭ , Sīrāf, Nishapur, Seleucia and at the East African sites of Manda, Kilwa and Kisimani Mafia (Blair, 2016:82). Here, elongated necks with parallels at Kush, Seleucia and Caesarea were also encountered (Blair,2016:315). What is more, we have not only encount closed early Islamic types, but also open types very well represented within early Islamic glasswares, such as the stepped rims vessels and the open vessels with folded rims (Blair,2016:92). Most of the stepped rims seem to be identified in the contexts at Nishapur, Sīrāf, Kush, Seleucia, Nippur, Qal'at

Seman (Syria), Yogne'am (Levant), Caesarea and Nippur (Blair,2016:92). A word finally about the outward-folded rims vessels uncovered here that were very common across the Early Islamic tradition. The latter are attested in Nishapur and Sīrāf. At Sīrāf the outwards-folded rims were very common. Our immediate concern was whether those glasses were entered Shanga through Sīrāf. Of course, as in the most cases there are no results coming from chemical analysis and such parallels do not offer clues to the trade activity. These are considerations, to which return repeatedly. But we are best informed that Horton based on the Arab and Persian world draw a picture of the imported glazed pottery from the Persian Gulf, glass and pearls to highlight the great importance of commerce at Shanga. Horton was of the opinion that Shanga by the 9th century AD was an integral part of the major ports of the Persian Gulf Sīrāf's and Sohar's trading networks that were extending to the Middle East and China (Horton,1987:89). The bulkier products, pottery from the Persian Gulf, glass, pearls, and Chinese stonewares of the Tang Dynasty could exchange with woods and slaves to drain the swamps of the Shatt-al-Arab on the Euphrates. The strong geographic location of Shanga, located on small surfaces in the edge of sea, where the dhows were beached and on 3,000 km of coast was ideal for Persian Gulf trade network (Allibert,1996:478). This pictures of dhows transporting from the 8th or 9th century AD pottery and glass probable unloaded from the Persian Gulf is continued further south in Chibuene, some 300 km off shore the Comoros archipelago in southern Mozambique (Wood, 2012:69;Blair,2016:32).

3.3.6 Chibuene

Chibuene on the rim of Vilanculos Bay represents one intriguing area that was engaged in the Indian Ocean trade (Blair,2016:32). Here, during excavations between 1977 and 1980 were catalogued 136 glass vessels (including 10 rims, 2 necks, 10 bases) and latter even more 413 mostly small glass shards (including 15 rims and 5 possible bases) during the excavations between 1995 to 1999 (Wood,2012:69). As far as can be made out, by integrating the new archaeological evidence, coming from the chemical analysis conducted by Marilee Wood (Wood,2012:59) of glass beads, vessels shards and wasters (glassworking debris, melted blods, cullet) from the 1995 to 1999 excavations, Chibuene turn to be the most important southerly 1st millenium trading hub known to have been participant in the Indian Ocean. Here, three types of plant ash glass

were recognized that they considered to be of Middle Eastern origin, containing low levels of alumina below <5% (Wood,2012:69). From the three sub-types the first ,designated as v-Na1, resembles 'Nishapur 1' glass, the second v-Na2 sets apart from other Middles Eastern samples and the third v-Na3 has any compositional similarity to any other particular assemblage from the Middle East (Wood,2016:69). Studying the glass Wood made a curious observation that over 10% of the shards have been scored with deeply incised lines uniform in width (single or multiple scored down the centre of long pointed shards) that were not just scratches or cracks as some have short feathered marks along the broken edges (***Figure 3.3.6.1***, Wood,2012:69); Wood was of the opinion that these were not part of the original surface design as were making no sense. Both the soda-plant-ash glass and the glass itself used for the Chibuene series beads were related probably with Persia and the environs. It was assumed that the glass vessels and beads together with exotic ceramics, cloths and probable pearls from the Persian Gulf were probable exchanged with ivory, animal hides, tortoise she ambergis (Wood,2012:72).

Since a large number glass shards were coming probably from Persia or environs it is, of course, tempting to think that there is a possibility that products to start their journey from Sīrāf's port. That consideration, however vague it may be, is strengthen by the fact that in the early occupation levels were uncovered two types of imported ceramics, the white glazed and blue splashed wares, and Sasanian Islamic pottery as well (Wood,2012:72). Furthermore, at Chibuene was identified a green glazed ware related with Iraq production (Wood,2012:60). So, there are reasons to believe that Chibuene was participating in the trans-oceanic trade complex trade network of the Persian Gulf ports; according to al-Ma'sudi (c. AD 893-957) (1861-77), cited in Wood (Wood,2012:72), Omani and Sīrāfi ships made voyages to Qanbalu and end voyages as far as Sofala to exchange their products with gold produced there and other wonderful things (ivory from elephant hunting). Products from a hinterland stretching over 1500 km from the east to west seems to reach Chibuene and might were exchanged with glass beads, as a large number of identical Chibuene beads were found there. Plant ash glass produced east of the Euphrates was used to produced different types of beads were found all over the Africa, such as the Zhizo series in southern Africa, the flat reheated beads from Zanzibar, Tung Tul, Gao Saney, Koumbi Saleh, the tubular beads from Igbo-Ukwu, the ground flat Kissi but Middle Eastern glass appear only in specific areas (Wood,2016:79). Through a glance to the whole chapter someone can easily observe that glasswares unearthed at sites from the African interior, West Africa and even North Africa were not mentioned. Early Islamic glass in association with glazed ceramics were uncovered from the two seasons of excavations in the city Gao, located on the River Niger. Generally, it is said that were imported via trans-Saharan trade coming from various regions of

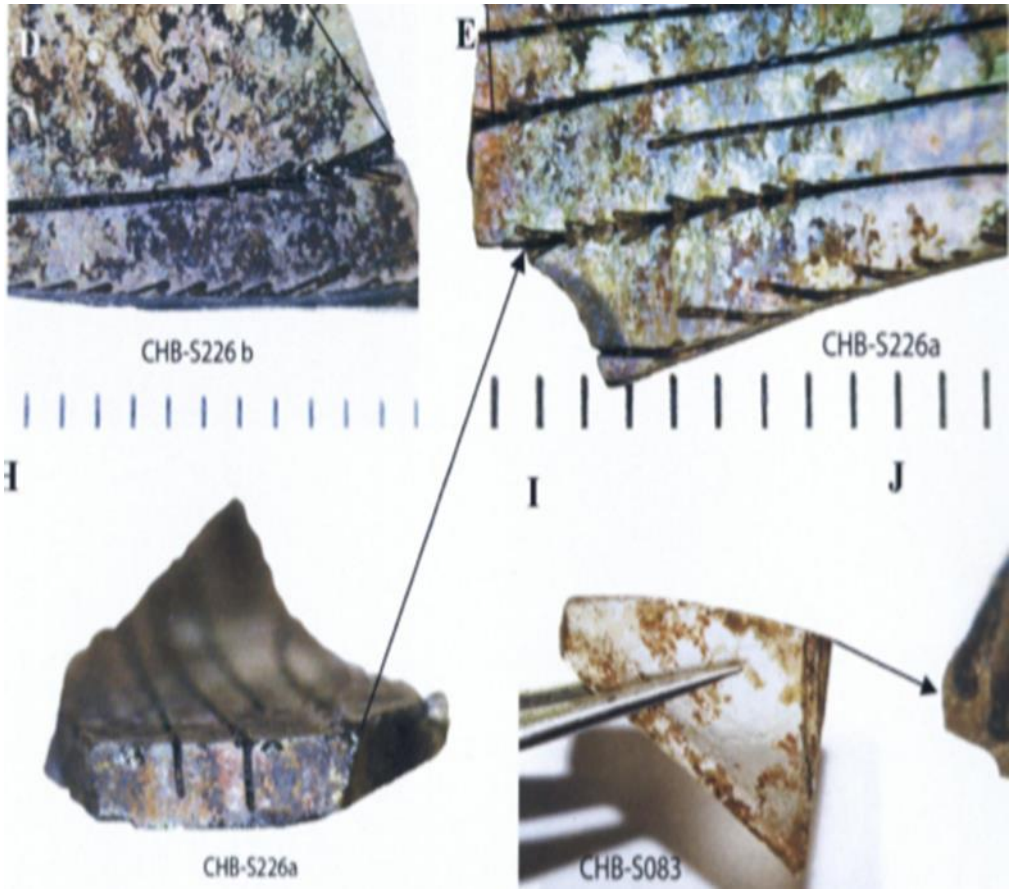


Figure 3.3.6.1: *Deeply incised lines have been scored on shards from Chibuene, Mozambique (Wood,2012:70).*

the Islamic world; even though here encountered scratched (wheel-abraded and incised), lustre-painted, cut, trailed (marvered and unmarvered) pinched, enameled and window glass unfortunately there are no results coming from the chemical analysis (Insoll,1998:77/80).

Even though early Islamic glass by the 9th and 10th centuries AD was certainly heading south along the West African gold trade routes vessel glass is more rarely encountered (Duckworth *et al.*,2016:633). Glass uncovered in the central Saharan region of Fazzan was not coming from the lands east of the Euphrates but from the Mediterranean lands according to the chemical analysis results; it is noteworthy that the glass vessels was kept for Garamantes use without to trade farther south (but this does not mean that glass vessels were not finding way south) (Duckworth *et al.*, 2016:638). But let see some thoughts about the absence of glass vessels in the African interior or why inhabitant prevent its diffusion. The absence of glass vessels within the African interior it can be related with a number of factors. There are thoughts that great demand on glass not yet existed there. If glass vessels were on demand they could easily being transported there along with other

exotics goods reached from the lands west and east of the Euphrates. It must be kept on mind that another reason could be that the desire of the inhabitants to prevent the diffusion of glass in the African interior as a sign of status to differentiate themselves from other inhabitants. Berthier was of the opinion that the absence of glass vessels is mainly attributed that the excavations are mainly focused on houses while glass was a luxury item and therefore rare was not dumped inside the houses (Wood,2016:87). It may also attribute to the fact that in the East African coast lived populations of different cultures and taste (Wood,2012:31). It is hoped that in the future if more chemical analysis will follow, especially from sites as Mogadishu, Kiwangwa, Mtapwa, Fukuchani, Mahilaka, Pang La Ukunju etch we will have a better understanding. For the moment it can be only said that in the East African coast early Islamic glass was reach indigenous settlements, initially surviving on local resources exploitation and craft production that were engaged in trade with the wider Indian Ocean region (Blair,2016:31).

CHAPTER 4

ARCHAEOLOGICAL BACKGROUND

4.1 The archaeological excavations at Kadhima, Mughaira and Shiqaya

4.1.1 Kadhima

In the modern Kadhima region, on the northern coastline of Kuwait Bay, archaeological evidence for an early Islamic occupation was identified by Sultan al-Duwish's survey work with the discovery of architectural remains dating to the early Islamic period along with material culture (Blair,2016:164). In 2009, Kadhima Project was established with the aim of archaeological exploration of northern Kuwait (***Figure 4.1.1.1,***Blair,Ulrich,2013:45, and see ***Figure 6.1.1***, Blair,2016:3,232). The excavations beginning in the winter of 2009 and concluding in the summer of 2015 were undertaken by Durham University and conducted jointly with the Kuwait National Museum (Blair,2016:164). A series of small settlements (Areas ABC, Area E, Area F, Area G) (***Figure 4.1.1.2***) and a total of 53 trenches were excavated (Blair,2016:165).

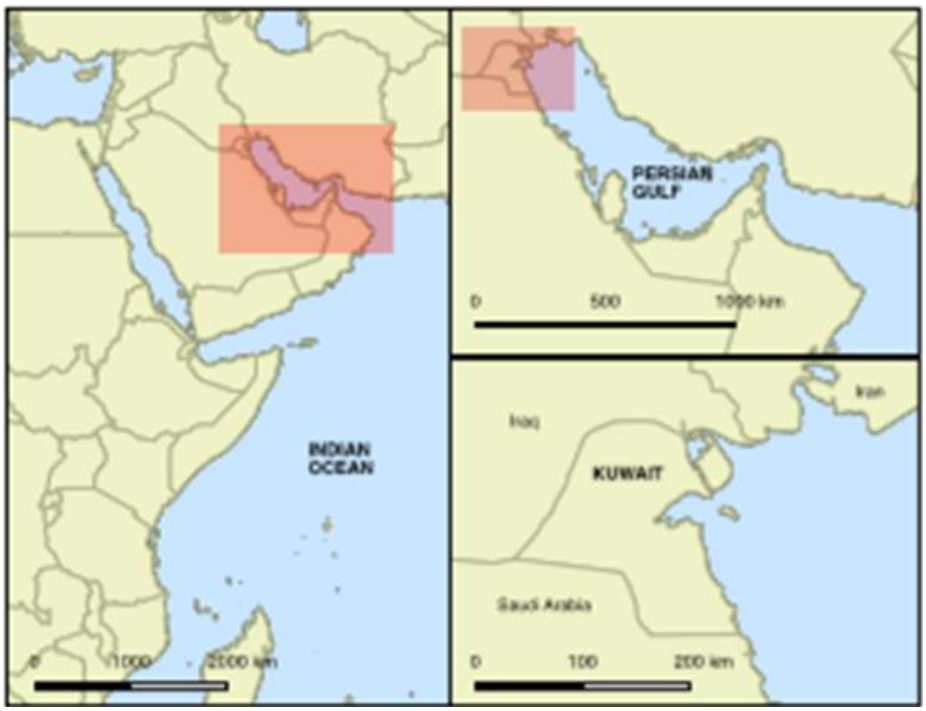


Figure 4.1.1.1: *The Kuwaiti study areas (created by Andrew Blair) (Blair,2016:3).*

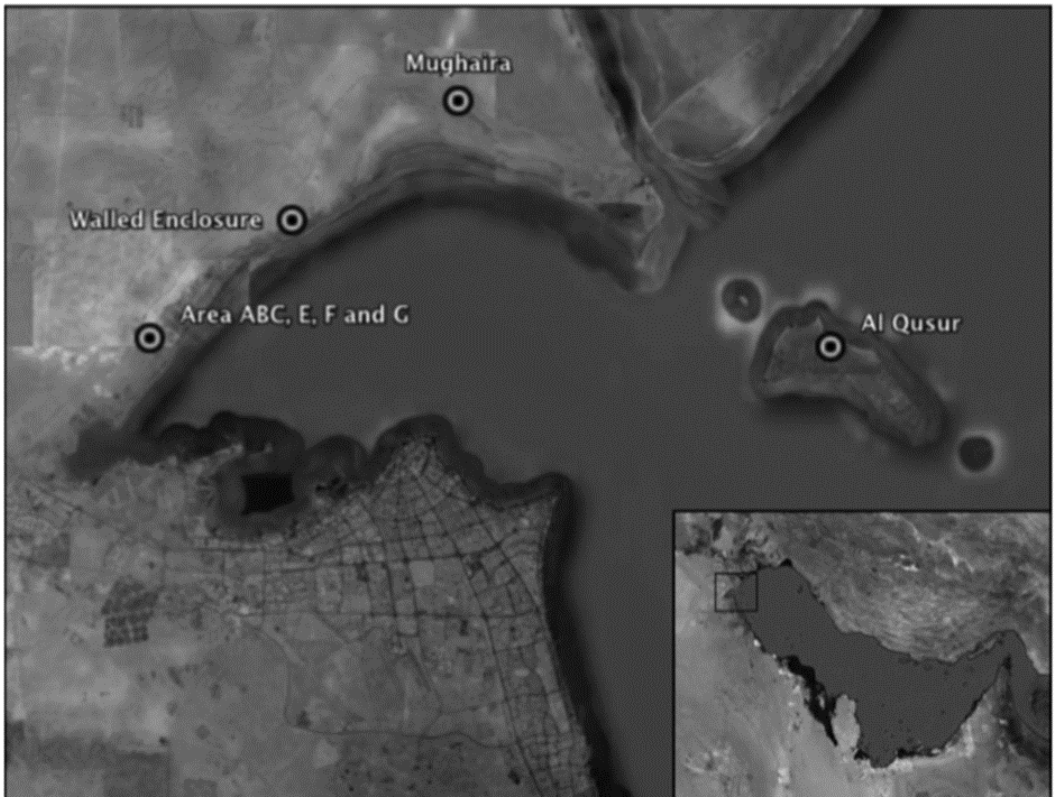


Figure 4.1.1.2: *A map of Kadhima showing the excavated areas ABC, E, F and G (created by Andrew Blair) (Blair et al,2012:14).*

A large mud-brick building (consisted of a multi-roomed structure superimposed upon an earlier timber-framed structure) (***Figure 4.1.1.3.***, Blair,2016:177), a well and a cistern complex were unearthed at an area that has been termed as **Area ABC**. A series of more ephemeral stone ('T-shaped', oval, square, stone) features, post holes, pits, and artefactual remains were also uncovered (Blair,2016:358). The main building may have been related to the administration of a well uncovered there and its resources (Blair,2016:170). Alongside the main building was uncovered a 'courtyard' area (***Figure 4.1.1.4.***, Blair,2016:362) that included a long mudbrick wall, a cobbled stone surface (which abutted a semi-circular arrangement of stones), several post-holes, a number of hearth features and a number of compact deposits (Blair,2016:362). The 'courtyard' brings evidence of considerable extramural activity (Blair,2016:170). South of the main building was located a well (surrounded by a ring of possible stone cisterns), a series of watering troughs and cistern complex (***Figure 4.1.1.5***, Blair,Ulrich,2013:48;Blair,2106:363). The cistern



Figure 4.1.1.3: *The large building at area ABC (Blair,2016:177).*



Figure 4.1.1.4: *The courtyard, with the structure in the background (Blair,2016:362).*

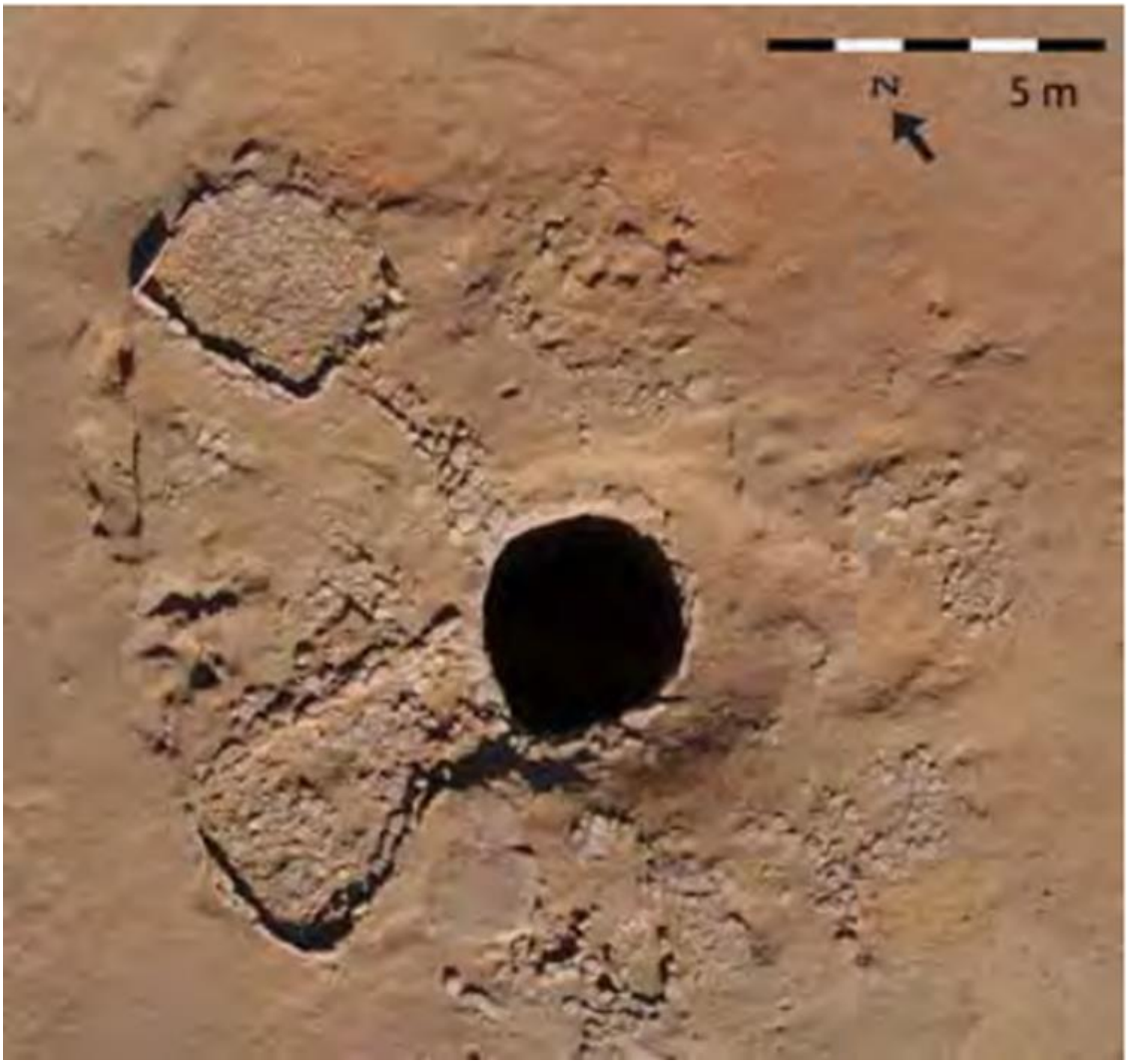


Figure 4.1.1.5: *The well and cisterns at Kadhima Area ABC (Blair,Ulrich,2013:48).*

complex consisted of a central stone-lined well shaft designated to facilitate the watering of multiple pack-animals.

A dense collection of artefacts (particularly pottery, glass and shell) was concentrated by ABC structures. The pottery contained at the first phase of the main building is dating back to the late 7th-8th century AD (Blair,2016:359). The ceramic evidence suggests that the well may have continued to be used after the 8th century AD buildings abandonment (Blair,2016:170). Nomadic groups may have continued to exploit later the water source (Blair,2016:364). The main building, the well and the cistern complex are dated according to the discovery of the widespread turquoise-glazed pottery from the mid-7th to the very early 9th century AD (Blair, 2016:365). This date seems to be supported by a coin dated to AD 760 and to the total absence

of the 9th century AD 'Sāmarrā Horizon' wares. The same chronology seems to share and the glass fragments analysed in the current study uncovered from the Area ABC (Blair,2106:171). In **Area E**, a main row of sub-rectilinear, single-roomed stoned buildings related with extra-mural activity were uncovered there consists of linear arrangement of (trapezoidal, sub-square, rectangular, oval) structures (***Figure 4.1.1.6***, ***Figure 4.1.1.7*** & ***Figure 4.1.1.8,*** Blair,2016:367,371). It seems that all those structures are dating back to the late 7th-8th century AD according to the ceramic assemblage and the absence of the 9th century AD 'Sāmarrā Horizon' (Blair,2016:373). North of the ABC Area was located **Area F**, which was partially excavated, with perhaps 25 trapezoidal structures. Here the density of the finds, uncovered at a linear arrangement of simple, singled-roomed buildings, were less than that found at the above-mentioned areas (Blair,2016:373). Six structures (square, oval stone, rectangular, semi-circular) were uncovered there (Figure Blair,2016:373). Finally, a word about the cemetery consisting of 76 graves that has been termed as **Area G**. Here there were not uncovered remains to provide conclusions about the chronology but the simple oval arrangement of the graves and their orientation suggests an Islamic date (Blair,2016:375). The excavations produced no grave goods (Islamic burial practice) and no glass fragments (Blair,2016:210).



Figure 4.1.1.6: *The area that has termed as Area E (Blair,2016:362).*

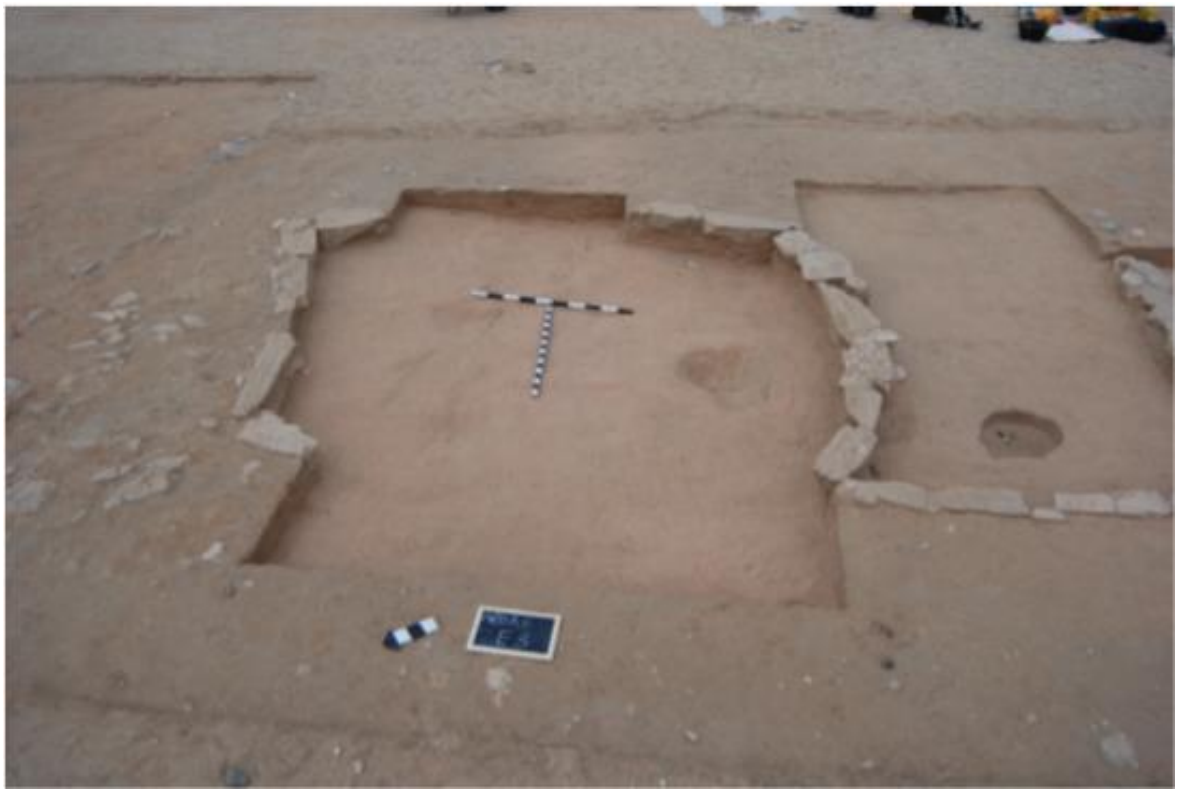


Figure 4.1.1.7: *Structure in Area E (Blair,2016:369).*



Figure 4.1.1.8: *Structure in Area E (Blair,2016:371).*

4.1.2 Mughaira

Work continued in the main site in Mughaira along an inland cliff and in its additional feature (structural and ephemeral 'stone features')(Blair,2016:379) where a total of 596 glass fragments were recorded there (Blair,2016:222). The site was divided into several hamlets with a range of architectural forms, including three discrete groupings along the cliff side and one linear group on top of a low ridge (Blair,2016:221,379). Into the linear group was identified a large building that was recorded as **LC233.22 - EX49** and into the cliff side were identified three buildings (***Figure 4.1.2.1***, Blair,2016:381;Blair,2016:379). A wealth of material culture was produced by the three-roomed stone-walled **LC233.22 - EX49** building, revealing extramural occupation in a 'courtyard area' (Blair,2016:221).



Figure 4.1.2.1: *The large building, LC233.22 - EX49 (Blair,2016:381).*

The building was the earliest stone structure (one of approximately 75 such features) that attested to an earlier timber structure, as a series of post-holes has shown (Blair,2016:381). A burnt feature, a stone platform and two stone protrusions were identified at the first floor of the building while at the second floor in the corner of the building was identified a stone box-like feature (Blair,2016:382). The central room was divided into the northeast room (an irregular floor of crushed bedrock was uncovered there) and the southwest room a later addition (Blair,2016:383). Outside **LC233.22 - EX49** building there was a courtyard where considerable activity took place as pits, postholes and burnt features has shown (Blair,2016:384). Around the main building can be found several satellite structures (Blair,2016:384). In the part of the site nearby to the cliff-edge three simple structures (architecturally identical to those seen in Area E above) produced very little material culture (only 83 glass fragments in contrast of 473 uncovered at LC233.22 - EX49 building) (Blair 2016:221). **LC233.50- EX50** building consisted of one main room which possessed three post-sockets along with a stone feature (***Figure 4.1.2.2***, Blair,2016:385).



Figure 4.1.2.2: *Room in EX50 (Blair,2016:385).*

A deposit probably pit was discovered there (Blair,2016:385). The second building (**LC233.48-EX52**) revealed a large number of post-holes with packing stones; fact that supports an assumption of pre-stone building phase (Blair,2016:388). A courtyard representing an extramural activity was found there contemporary with the use of the structure (Blair, 2016:388). Finally, at the third building (**LC233.49 -EX53**) a small account of cultural material was uncovered on a deposit pit coarse sand (Blair,2016:389). All the Kadhima settlements were probably occupied during the mid-7th to late 8th -9th century AD. This was supported by a series of C14 dates from the large building at EX49, the absence of Sāmarrā Horizon wares and the presence of turquoise wares (Blair,2016:389).

4.1.3 Shiqaya

Significant quantities of the 9th century AD 'Sāmarrā Horizon' pottery (cobalt blue and polychrome splash wares) were identified for the first time at the complex of archaeological remains at Shiqaya, probably the medieval al-Shajiya (***Figure 4.1.3.1***, Blair,Ulrich, 2013:47;Blair,2016:392). During the excavations at Shiqaya a large building with plastered wall and with possible three main rectangular rooms to the south and with smaller square to the north was uncovered (***Figure 4.1.3.2***, Blair,2016:393;Blair,2016:393). A number of single or double roomed structures were excavated (Blair,2016:393). South of the main building was unearthed a possibly cistern (central depression) and a possibly well (large doughnut-shaped mound) (Blair, 2016:393). The main building has a similar construction, even though larger, to the ´Abbāsid 'stations' along Darb Zubayda (Blair,2016:393). There is an assumption that Shiqaya was a way station on the main route from Baṣra to the Hijaz, designated to facilitate the need of pilgrims and other travellers (Blair,2016:241). The occupation of the building is dated late to 7th century AD until the 9th century AD while there is no evidence of later than the 9th century AD occupation (Blair,2016:240).



Figure 4.1.3.1: *Sāmarrā Horizon wares from Shiqaya (Blair,2016:394).*

A large number of cobalt blue and polychrome splash wares was identified for the first time in Kuwait during the excavations at the large building (Blair,2016:394). The so-called Sāmarrā horizon wares confirmed the 9th century AD occupation of the building while the absence of lustre and sgraffiato wares is an indication of an occupation earlier than the 10th century AD (Blair,2016:394). From the vicinity of the large building during the unsystematic survey were recorded 76 (undiagnostic body fragments, bases and a neck) glass fragments and from the well 4 fragments (Blair,2016:241). Glass seems to be more densely concentrated at Shiqaya than in any of the Kadhima region sites, but this may be related to environmental conditions (having been exposed more to sedimentation and less to erosion) (Blair,2016:244). A great range of variation in metals, forms and types was observed (Blair,2016:346). The range of colours and types of glasses presented in Shiqaya were not all presented on the coast fact that supports an assumption that Shiqaya was occupied during a later period than the coastal sites (Blair, 2016:346).



Figure 4.1.3.2: *The large building at Shiqaya (Blair,2016:393).*

4.2 The archaeological excavations at Unguja Ukuu

In Unguja Ukuu, located on Unguja Island which is the largest of the islands in the Zanzibar archipelago near the Tanzanian mainland, archaeological remains are found in a sheltered area on the southwest of the island (***Figure 4.2.1,*** Blair,2016:27,248). Unguja Ukuu was a vibrant trading emporium by the late 7th or early 8th century AD with a thriving proto-urban community with its eyes toward to the Indian Ocean (Blair,2016:249). In the early 20th century, the archaeological study of the site began with the visit of F.B. Pearce (Pearce,1920), while in 1960's Neville Chittick (Chittick,1960) brought the site to the attention (Blair,2016:250). But the dearth of upstanding remains led Chittick to concentrate on other stone towns elsewhere (Blair,2016:251). Surveys were conducted later by Mark Horton and Cathy Clark (Horton,Clark,1985) with excavations of several small test pits (Blair,2016:251).

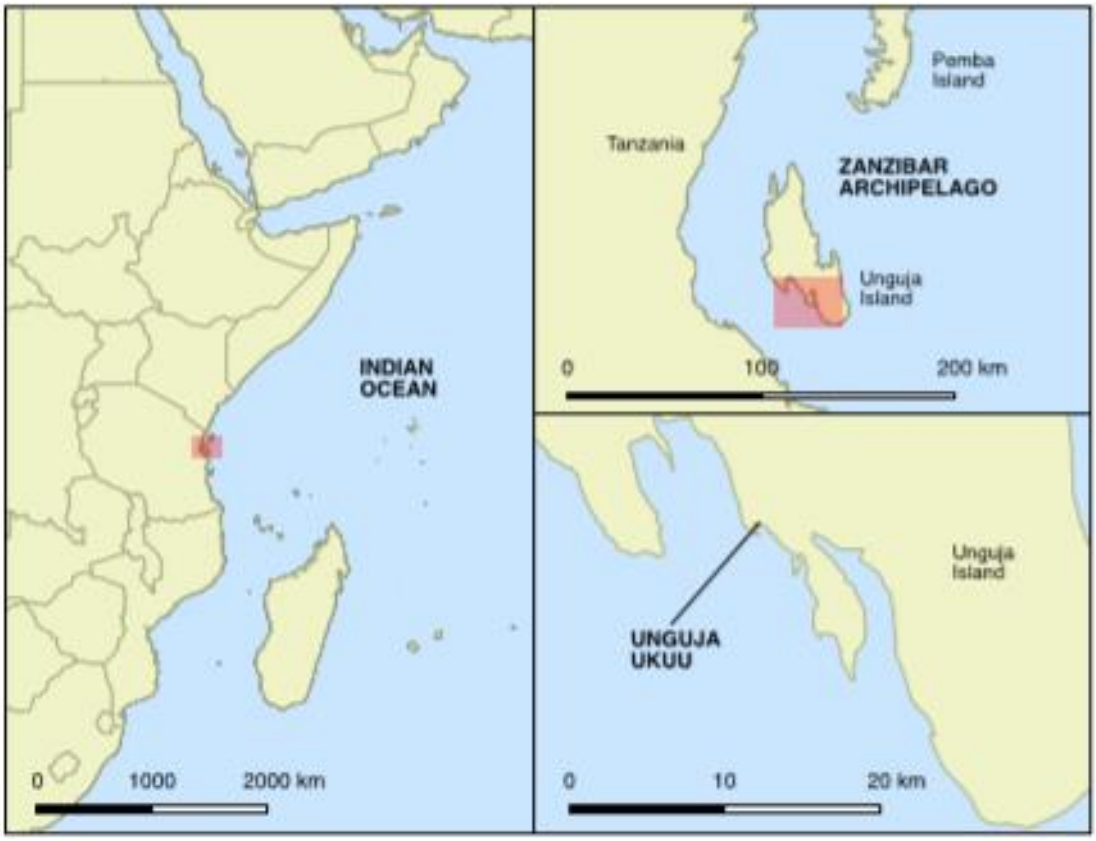


Figure 4.2.1: *Unguja Ukuu on the East African coast (created by Andrew Blair) (Blair,2016:248).*

Unguja Ukuu was studied later with the establishment of the Sealinks Project (trying to investigate early seafaring and long-distance connections between pre- and early historic communities occupying the Indian Ocean) (Blair,2016:253). More analytical, the project at Unguja Ukuu was established with the aims to identify evidence for an early occupation at the Zanzibar archipelago (Blair,2016:253). A total of six trenches were excavated stratigraphically to below 1.5 m depth (Blair,2016: 253). Among the artefacts that were recorded was glass from each of the six trenches (Blair,2016:253). Subchapter 4.2 will provide a brief overview of the fieldwork produced the glass assemblages.

The first trench that has termed as UU10 was located on the edge of a small mound south of the site; two pits related with waste disposal activities were uncovered there but signs of habitation suggesting that the pits were located on the edge of the main occupation (Blair,2016:255). A number of artefactual remains consist of ceramic dated to the 8th-9th century AD and 292 fragments of glass were also recovered (Blair,2016:255). The one pit (pit B) revealed two miscellaneous fragments of threads of glass which represent applied trail decoration and a rare cobalt blue scratched-engraved coloured glass (Blair,2016:258). The second trench that has termed as UU11 was located close to the modern beach revealing occupation evidence, even though no structural remains were found, and trading activity evidence (Blair,2016:261). In a context, described as ephemeral occupation, 166 fragments of glass were uncovered while a total of 570 fragments of glass were found in the trench (Blair,2016:262). Trailed and pinched glass was among the glass uncovered there (Blair,2016:264). At the same area as UU10 trench, south was located trench that has termed as UU12 revealing little glass (Blair,2016:266).

Behind the Menai Bay beach resort on the north-east side, was trench UU13; here midden deposits related to dumping activities were uncovered in Phase 1 (dated to the 7th-9th centuiries AD) while in Phase 2 (dated to the 10th-11th century AD) were uncovered a pit and a lime burning layer. Some sgraffiato pottery was uncovered in the Phase 2 and 42 fragments of glass at both phases (Blair,2016:268). At the fourth trench, termed as UU14, was concentrated the majority of the glass (1661 fragments) from Unguja Ukuu (Blair,2016:274). Among the glass fragments were found pieces of trailed, applied, pinched, dimpled and scratch-engraved glass (Blair,2016:278). Previously, at that area the excavator Abdurahman Juma (Juma,2004) identified late 5th century AD material (Blair,2016:271). The trench was located northeast of the modern beach (Blair,2016:271). Two periods were identified, the first (period I) was dated from the rich material of midden deposits to the mid-7th to 8th century AD and the second (period II) with a number of trampled floors dated to the late 8th to 9th century AD (Blair,2016:271). The site can

be associated with ephemeral occupation as there are absent structural features as a sign of habitation (Blair,2016:279). But timber structures were identified west of the trench UU13, in the so-called trench UU15; a number of post-holes were unearthed at the second phase of the site dated to the 7th -9th century AD(Blair,2016:281). The site was active at least until the 11th century as the sgraffiato pottery shows (Blair,2016:281). A number of glass fragments (662) were uncovered from all the trench phases (Blair,2016:281). From the first phase five threads of glass were uncovered while from the second phase was unearthed a rare Early Islamic glassware piece of mosaic or millefiori glass (Blair, 2016:284).

4.3 The archaeological excavations at Sīrāf

The excavations at Sīrāf, the chief emporium of the trade with the Far East, beginning in October of 1966 were sponsored by the British Institute of Persian Studies, with aim to investigate the development and commercial relations of the most prosperous port in the Persian Gulf (***Figure 4.3.1 & Figure 4.3.2***,Watts-Plumpkin,2006;Whitehouse,1968:1;Swan *et al.*,2017:103). During 1966's excavations in the face of a low cliff, an industrial complex, near the western edge of Sīrāf , walls, rubbish pits and kilns were uncovered associated with the ceramic and possibly glass production, dated probably to the 10th century AD (Whitehouse,1968:22;Swan *et al.*,2017:103). The location of the industrial complex was convenient for loading ships (Whitehouse,1968:12). David Whitehouse recorded the features and conducted excavation at a kiln exposed in a nearby gully (Whitehouse,1968:12). Here, in a yard enclosed by walls of mortared rubble was uncovered the kiln with a rubbish pit filled with wasters (Whitehouse,1968:12).

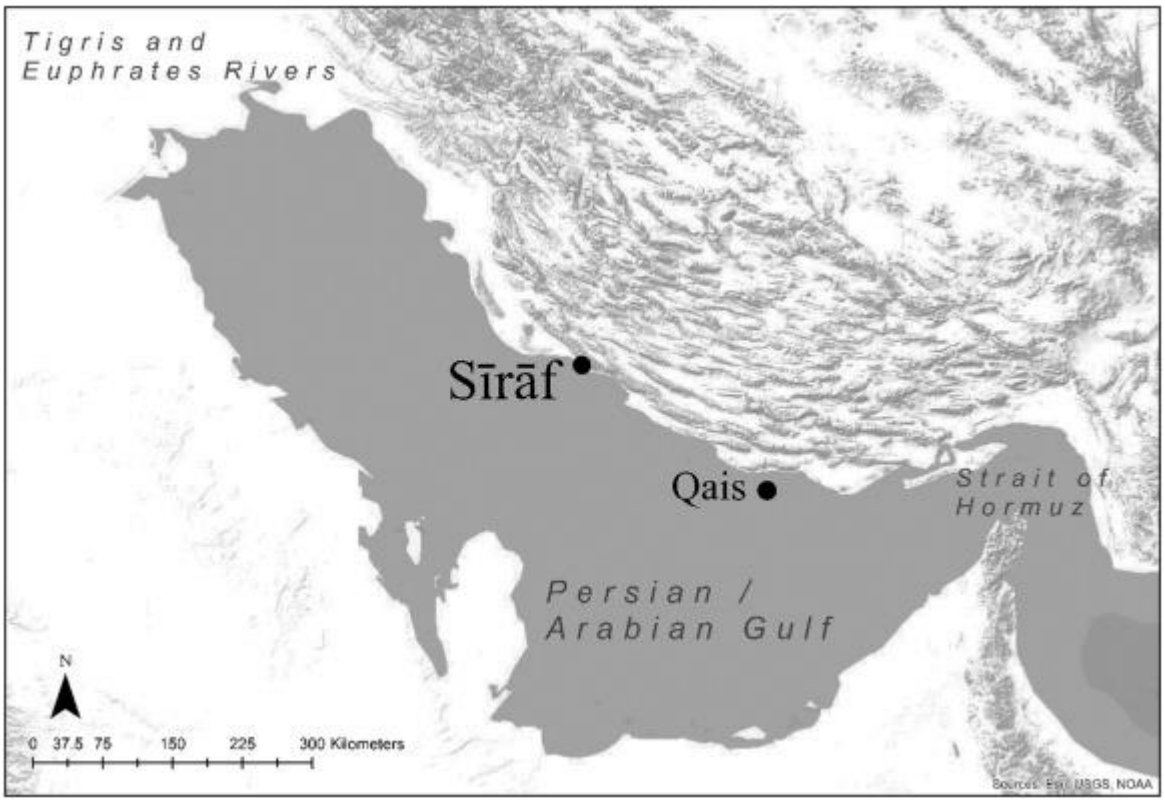


Figure 4.3.1: *Sīrāf on the Persian Gulf (Swan et al.,2017:103).*



Figure 4.3.2: *The principal remains of Sīrāf city (Emma Watts-Plumpkin,2006).*

David Whitehouse recorded the features and conducted excavation at a kiln exposed in a nearby gully (Whitehouse,1968:12). Here, in a yard enclosed by walls of mortared rubble was uncovered the kiln with a rubbish pit filled with wasters (Whitehouse,1968:12). The greatest part of the yard contained features that were not all contemporary; a number of trampled clay surfaces, a small pit, a kiln, a second kiln with the pillar and part of the floor surviving and a large rubbish pit were found there (Whitehouse,1968:12). The filling of all the features contained abundant coarse pottery wasters while the second kiln and a small pit yielded glass debris (drops, trails, glassy slag) and glass fragments (***Figure 4.3.3. & Figure 4.3.4.***, Whitehouse,1968:12;Swan *et al.*,2017:104). The occurrence of glass waste was an indication that glass was manufactured there (Whitehouse,1968:13). Much of the glass waste belong to the common types of glass at Sīrāf (Whitehouse,1968:13). In the north-east angle of the yard a kiln (constructed on an earlier kiln-like feature) and four rubbish pits were uncovered (Whitehouse,1968:13). The earlier kiln-like feature was an oval pit filled with wasters and kiln accessories (Whitehouse,1968:3). The clay-lined pit was roughly circular having a central pillar of clay and stone to support the floor of the upper chamber (Whitehouse,1968:13). It seems that the pit contained the fire, surmounted by a



Figure 4.3.3: *Glass fragments from Sīrāf within the Corning Museum of Glass collection (Swan et al,2017:104).*



Figure 4.3.4: *Glass fragments from Sīrāf within the Corning Museum of Glass collection (Swan et al,2017:104).*

chamber for the pots (Whitehouse,1968:13). At the side of the kiln was uncovered a circular stoke hole that providing access to the pit (Whitehouse,1968:13). We know next to nothing about the floor of the excavated kiln but we have the information that the floor of the west kiln was made of clay (Whitehouse,1968:13).

The most curious and interesting of the archaeological remains is the fact that all the pottery is unglazed and glazed wasters were not unearthed at the site that has termed as Site D. Nevertheless, the excavator was of the opinion that glazed pottery was made there (Whitehouse,1968:14). The excavation at Sīrāf yielded a number of blue-green glaze of the so-called 'Sasanian-Islamic' ware; the fragments were corroded making the original colour impossible to be seen (Whitehouse,1968:14). The blue-green glaze wares often bared applied, incised and stamped ornament (Whitehouse,1968:14). Among blue-green wares was uncovered white tin glaze pottery imitating Chinese white wares (Whitehouse,1968:15). Those wares have decoration with cobalt blue (epigraphic and floral motifs), turquoise and brown colour (spots, splashes) (Whitehouse,1968:15). Later and earlier types of Sgraffiato wares were also uncovered at the sit (Whitehouse,196815). When Sīrāf declined the most common pottery was the unglazed hand-made with painted decoration; finally, coarse pottery was also found. The excavation at Sīrāf yielded also a number glass fragments presented previously in subchapter 2.4 in Baṣra and Sīrāf section.

CHAPTER *5*

SCIENTIFIC TECHNIQUES AND STUDIED MATERIAL

5.1 Electron Probe Microanalysis (EPMA) and Scanning Electron Microscopy (SEM)

A wide range of sophisticated analytical techniques can employed to determine chemical composition of Kadhima, Mughaira, Shiqaya and Unguja Ukuu glasses, such as XRF (X-ray fluorescence), EDX (energy dispersive X-ray), WDS (wavelength dispersion spectroscopies), ICP-AES (inductively coupled plasma), PIXE (proton induced X-ray emission (PIXE) and INAA (neutron activation analysis), each with its own specific advantages, can be used here but EPMA and SEM are chosen (Palomar,2009:191). In most cases, especially in archaeology EPMA is chosen when the samples are of small size or valuable for other reasons. EPMA is a powerful technique, yet easy to use, and is capable of analysing elements heavier than or equal to beryllium with a spatial resolution of a few cubic micrometres and with detection limits for most elements down to 100 ppm or lower (Friel,1995:1;Llovet,2012:1). Accuracy approaching 1% can be obtained and can be attained detection limits down to tens of parts per million (by weight) (Reed,2005:1). The fundamental principles that needed for a sound understanding of electron microprobe analysis (EMPA) and the very close relative, which is designed for imaging rather than analysis, scanning electron microscopy (SEM), will be presented here.

The above techniques were used for chemically analyzing small selected areas of glass samples, utilizing characteristics X-rays excited by an electron beam (Reed,1993:xvii,Reed,2005:1). A brief and simplified description of EPMA and SEM will follow. More in-depth texts for a comprehensive account of both experimental and theoretical aspects of electron probe microanalysis and scanning electron microscopy can be found in the books by S.J.B. Reed (Electron Microprobe Analysis, First Edition (1975), Electron Microprobe Analysis, Second Edition (1993), Electron Microprobe Analysis and Scanning Electron Microscopy in Geology (2005)). The methods undertaken are nominally non-destructive and can provide a complete micro-scale qualitative and quantitative chemical analysis of inorganic solids a few micrometer in diameter (Reed,1993:xvii;Massachusetts Institute of Technology,2003:1;Reed,2005:1); EPMA enabled chemical analysis to be carried out non-destructively, although samples need to be mounted and polished, with a spatial resolution of 1 mm, as limited by the spreading of the beam on the sample (Reed,1993xvii). The sample preparation is minimal, but for accurate quantitative

analysis a well-polished surface is required (Chatterjee,2013:3). Samples are not damaged during analysis but can be reanalysed many times. EPMA and SEM are specific to the equipment available at 'The Open University' in the Environment, Earth and Ecosystem Sciences and at the 'University of Nottingham' in the Nanoscale and Microscale Research Centre (nmRC).

EPMA and SEM have now emerged as a versatile tool for archaeological science. X-rays are a great characterization tool at the hands of scientists working in archaeology for routine chemical analysis of small volumes. More specific, EPMA is extensively used for the determination of the chemical composition and microstructure of glass, ceramics, metals, steel, composite and advanced materials (Llovet,2012:5). Basically, a number of features make X-rays suitable to investigate the material of the archaeological object with particular emphasis on the provenance study(Kuleff,Djingova,Djingov,1986;Henderson,1988;Kuleff,Djingova,1996;Henderson,2000; Nikita,Henderson,2006;Palomar,2009:190). Provenance studies which are based on chemical composition are among the most popular investigations in archaeological science. The scientists used those methods to accurately determine the provenance of samples when macroscopic or typological criteria do not suffice. The basis of provenance studies is that the chemical composition of an artefact usually reflects the geochemical features of the raw materials it was made on. The solution of provenance problems may be reached after the analysis of a substantial number of samples and the creation of large chemical compositional databases. To accomplish chemical analysis, it is necessary an analytical instrumentation that resolves the chemical composition and the microstructure; for this reason, an analytical technique EPMA will be used to determine chemical composition of glass samples and an observation technique SEM to examine samples under high magnification (Palomar,2009:191).

The simplicity of characteristic x-ray spectra, their independence of the physical and chemical state, and the regular dependence of the wavelengths of lines on atomic number make the identification of the elements present a straightforward matter. Quantitative analysis may be performed by comparing the line intensities with those from pure elements or standard compounds of known composition (Reed,1993:xvii). EPMA is designed for the analysis (chemical composition) of very small materials or micro-domains that cannot be normally observed with the resolution offered by visible techniques (Reeds,1993:xvii;Friel,1995:1; Reed,2005:1;Llovet,2012:1). The analysts using the optical microscope can select specific analysis locations using the precision sample stage and make measurements while observing the sample (Donovan,1992:2). Under normal conditions, spatial resolution is limited to about 1 μm (Reed,1993:1;Friel,1995:1). EPMA combines the capabilities of both the scanning electron

microscope (SEM) and an X-ray fluorescence spectrometer (XRF) but with the added features of fine-spot focusing (~1 micrometer), optical microscope imaging, and precision-automated sample positioning (Reed,2001:1;Donovan,1992:2). Two hundred sixty glass fragments from Kadhima, Mughaira, Shiqaya and Unguja Ukuu will be analysed by EPMA and SEM. A table with the chemical compositions from each technique will be provided in Appendix 1. SEM resembles superficial with EPMA but its delivering analysis results are orders of magnitude worse (Holton,2012), so as to avoid misidentifications being made by automatic SEM results, this thesis is based only in EPMA results to provide meaningful groups. Although SEM has advanced a lot there are still hidden limitations (Holton,2012).

The new researchers must be not fooled by the superficial similarities between EPMA and SEM techniques (Holton,2012). EPMA provides higher spectral resolution, lower background (lower detection limits), higher order peaks (less escape peaks), more accurate (2-5% relative and reliable quantification of minor and trace elements (quant light elements), especially without detailed a priori knowledge of the specimen (Holton,2012). ***Figure 5.1.1*** shows an x-ray spectra with the same kinetic energy taken by SEM -EDS and EPMA-WDS respectively (Holton,2012). It is widely known that both techniques uses an electron-beam to stimulate x-ray emission from the sample but EPMA has an evident capability to routinely and accurately measure (detection of -100ppm) and quantify trace levels of a few tens of permils with fairly minimal effort (Holton,2012).

SEM can do major element analysis by measuring an intense peak against a relatively low background but cannot do trace element analysis as this analysis depends more on background characterization than upon peak counts (Holton,2012). For this and many other reasons we focus only in EPMA results. But which are the principles of EPMA? In the EPMA, a finely focused electron beam (generated by an electron gun) interacts with the samples to generate back-scattered electrons (BSE), secondary electrons (SE), characteristic X-rays and light known as cathodoluminescence (CL) (***Figure, 5.1.2***,Goodhew *et al.*,2001:126). ***Figure 5.1.3*** shows the interaction of the electron beam with the sample (Reed,1993;Reed,2005). The electron gun (a tungsten-filament thermionic) fired the electrons, which are accelerated to energy between 1 keV and 30 keV; then the electrons are demagnified by the condenser lenses until the beam hits the sample (Goodhew *et al.*,2001:126).

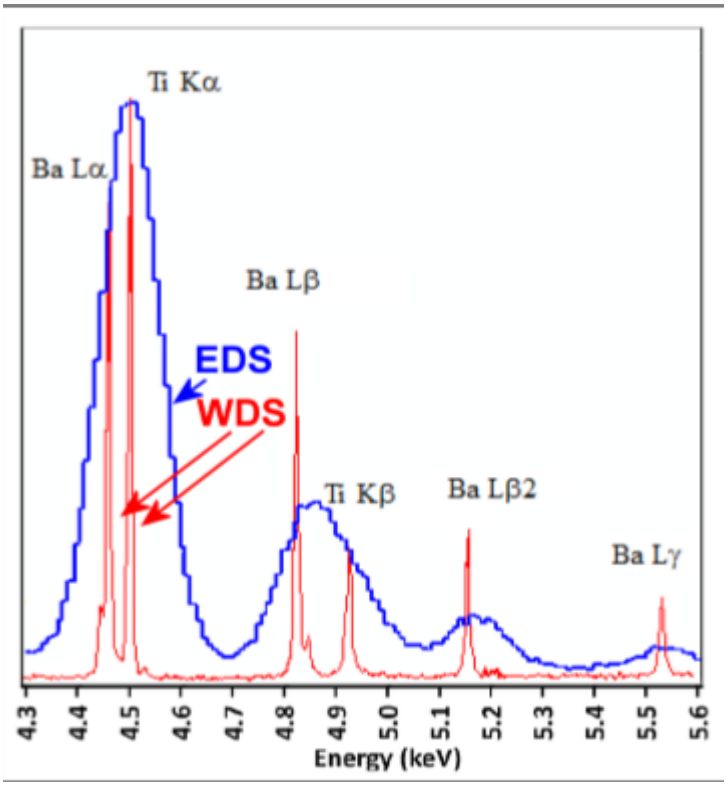


Figure 5.1.1: *X-ray spectra taken by SEM -EDS and EPMA-WDS respectively (Holton, 2012).*

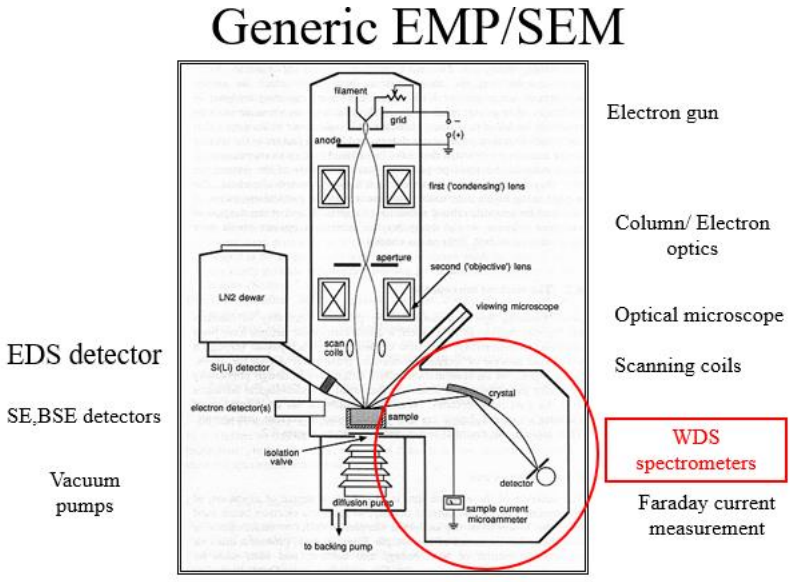


Figure 5.1.2: *An electron Microprobe (Madison Geology, 2016)*

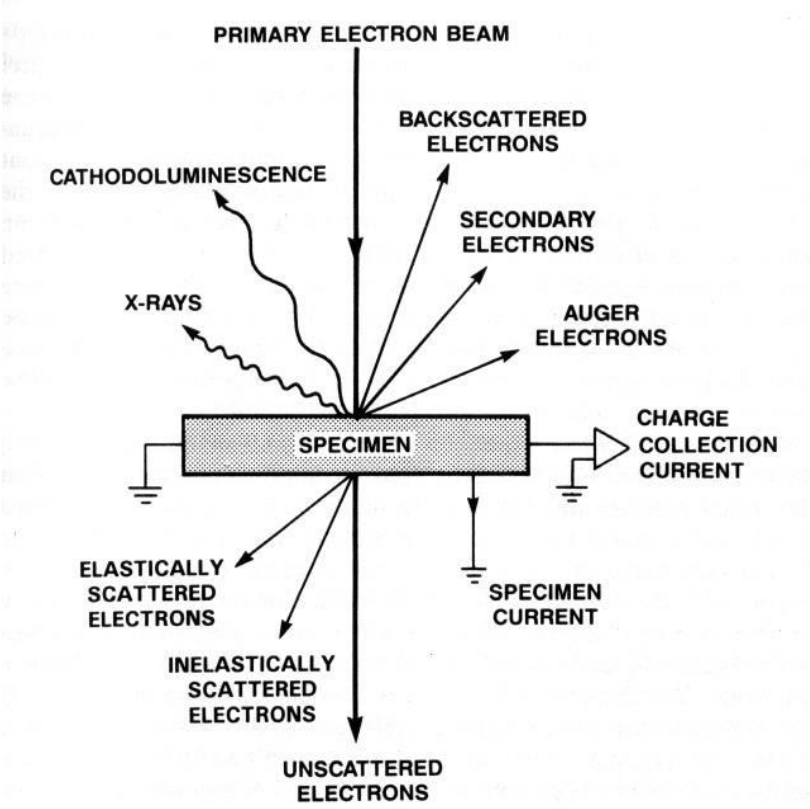


Figure 5.1.3: *An electron beam interaction with the specimen (Reed, 1993).*

Various energy emissions are generated in the region into which the electrons penetrate the sample (Goodhew *et al.*,2001:126). Those energy emissions, if they will not escape, can be measured appropriately. The characteristic X-rays are a form of electromagnetic energies in the range about 0.12-120 keV with, wavelengths of 10 to $10^{"2}$ nanometers (Reed,1993;Reed,2005). In electron microprobe microanalysis the X-rays excited by the electron beam dispersed by crystal with only one wavelength reflected and only one wavelength passed to the detector. The detector (a glass-filled) is a tube where gas is ionized by X-rays as to produce electrons which can be counted. X-ray focusing assumes geometry known as the Rowland Circle. The Electron Microprobe Analyzer identifies the lines of the X-ray spectrum from their wavelengths (or photon energies) and the elements present in microscopic volumes of the sample (Reed,2005:1, Chatterjee,2012:3;Llovet,2012:1). Each electron position has a specific energy, so that a fixed amount of energy absorbed or emitted by transitions of electron from one position to another

and each element has a specific pattern of emission or absorption. Energy is characterized as electromagnetic radiation or protons

(1) $\lambda = c / v$

where wavelength λ is inversely proportional to frequency v;

c =3 x 108 m/s.

(2) $E = h c / \lambda = h v$

where energy is inversely proportional to wavelength;

Planck's constant h = 6.626 x 10^{34} Js.

A primary X-ray beam used to excite the sample. When a sample is bombarded with this way any of electrons in the inner shells of an atom can be ejected, and the various electrons in the outer shells can drop to fill the void. Each transition from the L →K, M→ L, N→ M is accompanied by the emission of x-rays of characteristic energy and wavelength. Each transition has its own specific energy or lines. The quantity of emitted energy is equal to the difference in the electron energy levels

(3) $h\nu = E_K - E_L$

where hv is the energy taken to move from one electron state to another.

Three main types of transitions are labeled as K, L, and M. K series lines are of highest energy, followed by L and M in ***Figure 5.1.4.*** With the series the specific transitions are denoted by the subscripts α, β, γ etc. to denote which upper energy shell was involved in the relaxation and finally a numerical subscript to indicate the quantum state within the upper energy shell. One or two lines are normally sufficient for the positive identification of an element in qualitative terms. All elements give one or more series of characteristic emission lines. The number of these lines that are measurable depends upon the range and the separating ability of the WDX spectrometer. Since the intensity of emission is directly proportional to the number of atoms emitting, both the identity and quantity of each element may be determined. The specific elements can be recorded in the form of lines profiles or two-dimensional 'maps', which are commonly displayed using a 'false' colour scale to represent elemental concentrations (Reed, 1993:1). Quantitative analysis can also be conducted by measuring the intensity of the peaks and

by counting the number of characteristic X-ray from the sample within a fixed interval of time when compared with the number arriving from standard samples (pure elements or compounds of the same composition) within the same interval. Thus, the Electronprobe Micro Analyser is able to determine the concentration of each element in the sample (Reed,2005:1); hence a qualitative and quantitative analysis is easy to obtain (Reed,2005:1). The concentration of the element is given by

(4) $$C_{spec} = N_{spec}/N_{std} \times C_{std} = k \times C_{std}$$

where spec= specimen

std=standard

C_{std} = is the known concentration in the standard

N= is the peak count minus background count

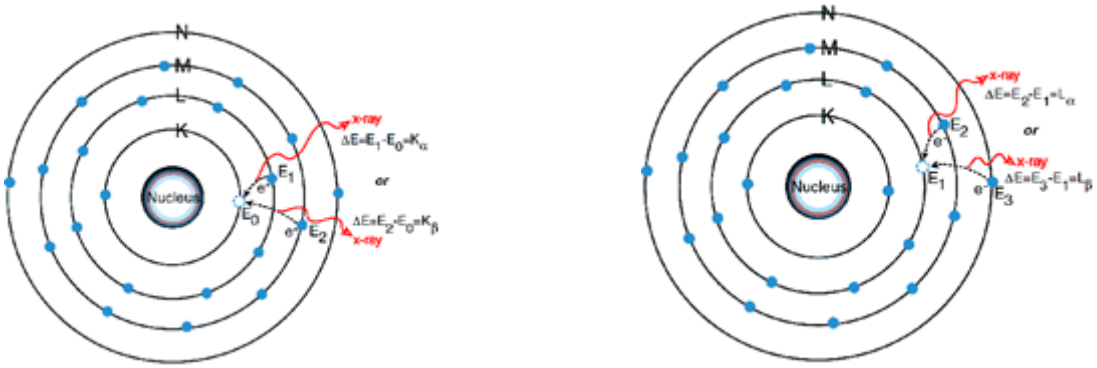


Figure 5.1.4: The transition of the electrons.

5.2 Method and studied material

Two hundred sixty samples stored at the Durham University (**Table 5.1**), for this thesis, between 2 and 4mm, were arranged in plastic moulds (10 samples per mould) lined with a Buehler Released Agent. **Table 5.2** shows the colours mentioned at **Table 5.1**. The Buehler epoxy resin allowed to dry for 16 hours at room temperature. Then the resin blocks were ground and polished to reveal the surface of the samples. The scratches were removed together with fine lines which might interfere the electron probe microanalysis. The scratches were removed by grounding/polished the samples in a single direction and then rotated by 90º in between each stage. An optical reflected light microscope was used as to examine the polished samples. The resin blocks were photographed under a reflected light microscope. At the final stage, the samples were cleaned in a sonic bath and coated with a thin layer of carbon (Emitech K550X carbon coater). Sixteen resin blocks consists of 160 samples were analysed in the Nanoscale and Microscale Center at the University of Nottingham with a JEOL JXA-8200 electron microprobe system (EPMA) with four wavelength-dispersive will used for the determination of the major and minor elements and a Scanning Electron microscopy (SEM) for the determination of the major and minor elements. Ten resin blocks consists of 100 samples were also send to the Open University and were analysed with a CAMECA SX100 microprobe.

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL82	Closed	Flaring - straight		Rim	LGB 'Light green-blue'	ABC SURVEY			
GL1234	Closed	Flaring - straight	Applied (trail)	Rim	CL 'Colourless'	ABC	EX27	CX256	mid-7th to the very early 9th century AD
GL1004	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX4	CX152	mid-7th to the very early 9th century AD
GL0838	Closed	Flaring - straight		Rim	OG 'Olive green'	E	EX6	CX78	mid-7th to the very early 9th century AD
GL1062	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX4	CX96/152	mid-7th to the very early 9th century AD
GL773	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX4	CX12	mid-7th to the very early 9th century AD
GL2041	Closed	Flaring - straight		Rim	COR 'weathered'	MUG	EX49	CX677	mid-7th to the very early 9th century AD
GL1060	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX4	CX21	mid-7th to the very early 9th century AD
GL1060	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX4	CX21	mid-7th to the very early 9th century AD
GL1132	Closed	Flaring - Straight		Rim	OG 'Olive green'	ABC	EX27	CX251	mid-7th to the very early 9th century AD
GL0732	Undiagnostic	U		Body	COR 'weathered'	E	EX4	CX12	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1213	Closed	Flaring - straight		Rim	COR 'weathered'	ABC	EX27	CX254	mid-7th to the very early 9th century AD
GL1234	Closed	Flaring - straight	Applied (trail)	Rim	CL 'Colourless'	ABC	EX27	CX256	mid-7th to the very early 9th century AD
GL2045	Closed	Flaring - straight		Rim	COR 'weathered'	MUG	EX49	CX767	mid-7th to the very early 9th century AD
GL1674	Closed	Flaring - straight		Rim	COR 'weathered'	MUG	EX49	CX645	mid-7th to the very early 9th century AD
GL1114	Closed	Flaring - straight		Rim	CL 'Colourless' glass	E	EX13	CX60	mid-7th to the very early 9th century AD
GL0957	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX4	CX97	mid-7th to the very early 9th century AD
GL0778	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX2	CX17	mid-7th to the very early 9th century AD
GL0998	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX2	CX216	mid-7th to the very early 9th century AD
GL0651	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX2	CX10	mid-7th to the very early 9th century AD
GL15	Closed	Flaring - straight		Rim	CL 'Colourless'	TR			

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL0008	Closed	Flaring - straight		Rim	CL 'Colourless'	TR			
GL0779	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX5	CX41	mid-7th to the very early 9th century AD
GL0559	Closed	Flaring - straight		Rim	OG 'Olive green'	E SURVEY			
GL1844	Closed	Flaring - straight		Rim	COR 'weathered'	MUG	EX49	CX717	mid-7th to the very early 9th century AD
GL1039	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX7	CX217	mid-7th to the very early 9th century AD
GL1072	Closed	Flaring - straight		Rim	COR 'weathered'	E	EX4	CX96	mid-7th to the very early 9th century AD
GL0953	Open	Rolled-in rim		Rim	COR 'weathered'	E	EX2	CX211	mid-7th to the very early 9th century AD
GL0149	Open	Rolled-in rim		Rim	COR 'weathered'	ABC SURVEY			
GL0861	Open	Rolled-in rim		Rim	COR 'weathered'	E	EX6	CX78	mid-7th to the very early 9th century AD
GL1230	Open	Rolled-in rim		Rim	COR 'weathered'	ABC	EX28	CX289	mid-7th to the very early 9th century AD
GL1335	Open	Stepped rim		Rim	OG 'olive green'	SH			late 7th to 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1364	Open	Stepped rim		Rim	LGB 'light green-blue'	SH			late 7th to 9th century AD
GL1329	Open	Stepped rim		Rim	CL 'colourless'	SH			late 7th to 9th century AD
GL1351	Open	Stepped rim		Rim	LGB 'light green-blue'	SH			late 7th to 9th century AD
GL1371	Open	Stepped rim		Rim	LGB 'light green-blue'	SH			late 7th to 9th century AD
GL1356	Open	Stepped rim		Rim	LGB 'light green-blue'	SH			late 7th to 9th century AD
GL0084	Open	Stepped rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL0898	Open	Stepped rim		Rim	COR 'weathered'	E	EX4	CX97	mid-7th to the very early 9th century AD
GL0771	Open	Stepped rim		Rim	COR 'weathered'	E	EX4	CX12	mid-7th to the very early 9th century AD
GL1577	Open	Stepped rim		Rim	COR 'weathered'	ABC	EX27	CX322	mid-7th to the very early 9th century AD
GL1435	Open	Stepped rim		Rim	COR 'weathered'	ABC	EX28	CX301	mid-7th to the very early 9th century AD
GL1302	Open	Stepped rim		Rim	COR 'weathered'	ABC	EX27	CX254	mid-7th to the very early 9th century AD
GL0258	Open	Stepped rim		Rim	EG	ABC SURVEY			

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL0584	Open	Stepped rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL1461	Open	Stepped rim		Rim	COR 'weathered'	ABC	EX27	CX349	mid-7th to the very early 9th century AD
GL1009	Open	Stepped rim		Rim	COR 'weathered'	E	EX4	CX152	mid-7th to the very early 9th century AD
GL1007	Open	Stepped rim		Rim	COR	E	EX4	CX152	mid-7th to the very early 9th century AD
GL0748	Open	Stepped rim		Rim	COR	E	EX4	CX70	mid-7th to the very early 9th century AD
GL0299	Open	Stepped rim		Rim	LGB	ABC SURVEY			
GL1474	Open	Stepped rim		Rim	COR	ABC	EX27	CX400	mid-7th to the very early 9th century AD
GL1547	Open	Triangular beaked rim		Rim	COR 'weathered'	ABC	EX31	CX490	
GL0080	Open	Triangular beaked rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL1603	Open	Triangular beaked rim		Rim	LGB 'light green-blue'	MUG	EX49	CX629	mid-7th to the very early 9th century AD
GL0236	Open	Triangular beaked rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL1588	Open	Triangular beaked rim		Rim	EG 'emerald-green'	MUG	EX49	CX629	mid-7th to the very early 9th century AD
GL0014	Open	Triangular beaked rim		Rim	EG	TR			

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL0233	Open	Triangular beaked rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL1677	Open	Triangular beaked rim		Rim	COR 'weathered'	MUG	EX49	CX664	mid-7th to the very early 9th century AD
GL1152	Open	Triangular beaked rim		Rim	LGB 'light green-blue'	ABC	EX27	CX251	
GL0234	Open	Triangular beaked rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL1856	Open	Triangular beaked rim		Rim	COR 'weathered'	MUG	EX49	CX723	mid-7th to the very early 9th century AD
GL1680	Open	Triangular beaked rim		Rim	COR 'weathered'	MUG	EX49	CX667	mid-7th to the very early 9th century AD
GL0083	Open	Triangular beaked rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL0660	Open	Flaring-sided		Rim	IB 'ice-blue'	E	EX7	CX27	mid-7th to the very early 9th century AD
GL1051	Open	Flaring-sided		Rim	IB 'ice-blue'	E	EX7	CX217	mid-7th to the very early 9th century AD
GL1798	Closed	Folded and flattened rim		Rim	COR 'weathered'	MUG	EX49	CX675	mid-7th to the very early 9th century AD
GL1363	Open	Plain - rounded		Rim	IB 'ice-blue'	SH			late 7th to 9th century AD
GL1848	Closed	Plain vertical neck		Rim	CL 'colourless'	SH			late 7th to 9th century AD
GL0085	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	ABC SURVEY			

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL0151	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL1077	Open	Inwards-folded rim		Rim	COR 'weathered'	E	EX4	CX96	mid-7th to the very early 9th century AD
GL0007	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	TR			early Islamic period
GL0534	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	F SURVEY			early Islamic period
GL1556	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	ABC	EX40	CX497	mid-7th to the very early 9th century AD
GL0639	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	E	EX6	CX26	mid-7th to the very early 9th century AD
GL0659	Open	Inwards-folded rim		Rim	LGB	E	EX7	CX27	mid-7th to the very early 9th century AD
GL1947	Open	Inwards-folded rim		Rim	COR 'weathered'	MUG	EX49	CX767	mid-7th to the very early 9th century AD
GL1786	Open	Inwards-folded rim		Rim	COR 'weathered'	MUG	EX49	CX675	mid-7th to the very early 9th century AD
GL0152	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL0269	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL1239	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	MUG	EX36	CX298	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL0150	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL0061	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL1118	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	ABC	EX27	CX251	mid-7th to the very early 9th century AD
GL1662	Open	Inwards-folded rim		Rim	COR 'weathered'	MUG	EX49	CX631	mid-7th to the very early 9th century AD
GL1561	Open	Inwards-folded rim		Rim	COR 'weathered'	ABC	EX27	CX251	mid-7th to the very early 9th century AD
GL0634	Open	Inwards-folded rim		Rim	COR 'weathered'	E	EX4	CX37	mid-7th to the very early 9th century AD
GL1024	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	BH			
GL1808	Open	Inwards-folded rim		Rim	LGB 'light green-blue'	MUG	EX49	CX629/631	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1223	Closed	Folded and flattened rim		Rim	COR 'weathered'	ABC	EX27	CX256	mid-7th to the very early 9th century AD
GL1381	Closed	Folded and flattened rim		Rim	COR 'weathered'	ABC	EX27	CX254	mid-7th to the very early 9th century AD
GL0081	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL0361	Closed	Folded and flattened rim		Rim	OG 'olive green'	ABC SURVEY			
GL1761	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	MUG	EX49	CX631	mid-7th to the very early 9th century AD
GL1323	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	SH			late 7th to 9th century AD
GL0719	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	E SURVEY			
GL1944	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	MUG	EX50	CX805	mid-7th to the very early 9th century AD
GL0718	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	E SURVEY			

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1599	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	MUG	EX49	CX629	mid-7th to the very early 9th century AD
GL0725	Closed	Folded and flattened rim		Rim	COR 'weathered'	E	EX4	CX12	mid-7th to the very early 9th century AD
GL2068	Closed	Folded and flattened rim		Rim	COR 'weathered'	MUG	EX49	CX783	mid-7th to the very early 9th century AD
GL0652	Closed	Folded and flattened rim		Rim	COR 'weathered'	E	EX5	CX38	mid-7th to the very early 9th century AD
GL0346	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL0854	Closed	Folded and flattened rim		Rim	COR 'weathered'	E	EX6	CX78	mid-7th to the very early 9th century AD
GL0398	Closed	Folded and flattened rim		Rim	EG 'emerald-green'	E SURVEY			
GL1649	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	MUG	EX49	CX631	mid-7th to the very early 9th century AD
GL0644	Closed	Folded and flattened rim		Rim	COR 'weathered'	E	EX4	CX21	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL0986	Closed	Folded and flattened rim		Rim	COR 'weathered'	E	EX4	CX21	mid-7th to the very early 9th century AD
GL2068	Closed	Folded and flattened rim		Rim	COR 'weathered'	MUG	EX49	CX783	mid-7th to the very early 9th century AD
GL0652	Closed	Folded and flattened rim		Rim	COR 'weathered'	E	EX5	CX38	mid-7th to the very early 9th century AD
GL0346	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL0854	Closed	Folded and flattened rim		Rim	COR 'weathered'	E	EX6	CX78	mid-7th to the very early 9th century AD
GL0398	Closed	Folded and flattened rim		Rim	EG 'emerald-green'	E SURVEY			
GL1649	Closed	Folded and flattened rim		Rim	LGB 'light green-blue'	MUG	EX49	CX631	mid-7th to the very early 9th century AD
GL0644	Closed	Folded and flattened rim		Rim	COR 'weathered'	E	EX4	CX21	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1836	Closed	Folded and flattened rim		Rim	COR 'weathered'	MUG	EX49	CX734	mid-7th to the very early 9th century AD
GL1530	Closed	Folded and flattened rim		Rim	COR 'weathered'	ABC	EX27	CX446	mid-7th to the very early 9th century AD
GL1995	Closed	Flaring - rolled-in rim		Rim	COR 'weathered'	MUG	EX50	CX806	
GL0396	Closed	Flaring - rolled-in rim		Rim	OG 'olive green'	E SURVEY			
GL1236	Closed	Flaring - rolled-in rim		Rim	COR 'weathered'	ABC	EX28	CX289	mid-7th to the very early 9th century AD
GL1574	Closed	Flaring - rolled-in rim		Rim	COR 'weathered'	FORT	EX33	CX518	Early Islamic period
GL0721	Undiagnostic	U		Body	OG 'olive green'	E SURVEY			
GL0235	Closed	Flaring - rolled-in rim		Rim	LGB 'light green-blue'	ABC SURVEY			
GL0155	Closed	Flaring - rolled-in rim		Rim	LGB 'light green-blue'	ABC SURVEY			

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIAQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1264	Closed	Ribbed - narrow		Rim	COR 'weathered'	ABC	EX27	CX254	mid-7th to the very early 9th century AD
GL1308	Closed	Ribbed - narrow		Rim	CL 'colourless'	SH			
GL1392	Open	Plain - fine	Dimpled	Rim	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1393	Push-up	6	Dimpled	Base	COR 'weathered'	ABC	EX27	CX255	
GL1394	Open	Plain - fine	Dimpled	Rim	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1395	Open	Plain - fine	Dimpled	Rim	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1396	Open	Plain - fine	Dimpled	Rim	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1397	Open	Plain - fine	Dimpled	Rim	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1398	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1399	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1400	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL0149	Open	Rolled-in rim		Rim	COR 'weathered'	ABC SURVEY			
GL1402	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1403	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1404	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1405	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1406	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number		Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1407		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1408		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1409		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1410		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1411		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1412		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1413		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1414		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1415		Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL1416	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1417	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1418	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL1419	Open	Plain - fine	Dimpled	Body	COR 'weathered'	ABC	EX27	CX255	mid-7th to the very early 9th century AD
GL2142	Closed	Flaring - concave		Rim	COR 'weathered'	MUG	EX52	CX808	
GL0735	Undiagnostic	U		Body	COR 'weathered'	E	EX4	CX72	
GL1269	Closed	Ribbed - narrow		Rim	COR 'weathered'	ABC	EX27	CX256	mid-7th to the very early 9th century AD
GL0897	Closed	Ribbed - narrow		Rim	COR 'weathered'	E	EX4	CX118	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM KADHIMA, MUGHAIRA AND SHIQAYA

GL Number	Form	Type	Decoration	ID	Colour	Area	Trench	Context	Date
GL0932	Undiagnostic	U		Body	COR 'weathered'	E	EX4	CX21	mid-7th to the very early 9th century AD
GL0692	Closed	Ribbed - narrow		Rim	COR 'weathered'	E	EX4	CX37	mid-7th to the very early 9th century AD
GL0232	Open	Plain - fine		Rim	COR 'weathered'	E SURVEY			
GL1281	Open	Plain - fine		Rim	COR 'weathered'	ABC	EX27	CX254	mid-7th to the very early 9th century AD
GL1003	Open	Plain - fine		Rim	COR 'weathered'	E	EX5	CX151	mid-7th to the very early 9th century AD
GL1616	Open	Plain - fine		Rim	LGB 'light green-blue'	MUG	EX49	CX629	mid-7th to the very early 9th century AD
GL0640	Open	Plain - fine		Rim	LGB 'light green-blue'	E	EX6	CX26	mid-7th to the very early 9th century AD
GL1675	Open	Plain - fine		Rim	LGB 'light green-blue'	MUG	EX49	CX650	mid-7th to the very early 9th century AD
GL1913	Open	Plain - fine		Rim	COR 'weathered'	MUG	EX49	CX723	mid-7th to the very early 9th century AD
GL1836	Closed	Folded and flattened rim		Rim	COR 'weathered'	MUG	EX49	CX734	mid-7th to the very early 9th century AD

Table 5. 1

STUDIED MATERIAL FROM UNGUJA UKUU

GL Number	Form	Type	Decoration	ID	Colour	Trench	Context	Date
GL0832	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU11	017	mid-7th to 8th century AD
GL0765	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU11	017	mid-7th to 8th century AD
GL0715	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU11	017	mid-7th to 8th century AD
GL1999	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU14	1439	mid-7th to late-8th century AD
GL0710	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU11	017	mid-7th to 8th century AD
GL2933	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU14	1408 w/s	9th century AD
GL0764	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU11	017	mid-7th to 8th century AD
GL1855	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU14	1404e	9th century AD
GL0712	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU11	017	mid-7th to 8th century AD
GL0090	Undiagnostic	U	Scratch-engraved	Body	BL 'blue'	UU10	004	8th-9th century AD
GL2244	Open	Stepped rim	Scratch-engraved	Rim	BL 'blue'	UU14	1438	mid-7th to late-8th century AD
GL2846	Undiagnostic	U	Scratch-engraved	Body	BL 'blue'	UU14	1420m	9th century AD
GL3461	Application	Applied trail	Applied (trail)	Misc	TQ 'turquoise'	UU15	1551L	mid-7th to 9th century AD

Table 5. 1

STUDIED MATERIAL FROM UNGUJA UKUU

GL Number	Form	Type	Decoration	ID	Colour	Trench	Context	Date
GL3257	Application	Applied trail	Applied (trail)	Misc	OG 'olive green'	UU15	1556 N	mid-7th to 9th century AD
GL3306	Application	Applied trail	Applied (trail)	Misc	OG 'olive green'	UU15	1510	late 10th to 11th century AD
GL0201	Application	Applied trail	Applied (trail)	Misc	CL 'colourless'	UU10	006	8th-9th century AD
GL0213	Application	Applied trail	Applied (trail)	Misc	OG 'olive green'	UU10	007	8th-9th century AD
GL2975	Application	Applied trail	Applied (trail)	Misc	OG 'olive green'	UU14	1414 or 1444	mid-7th to late-8th century AD
GL3145	Undiagnostic	U	Mosaic	Body	MOSAIC	UU15	1511	7th-9th century AD
GL0143	Semi-open	Vertical neck - wide	_	Rim	IB 'ice-blue'	UU10	005	8th-9th century AD
GL1337	Semi-open	Vertical neck - wide	_	Rim	CL 'colourless'	UU14	1404 d	9th century AD
GL0382	Semi-open	Vertical neck - wide	_	Rim	CL 'colourless'	UU11	004	mid-7th to 8th century AD
GL0904	Closed	Neck B	_	Rim	CL 'colourless'	UU13	006	7th-9th century AD
GL2100	Closed	Neck A	_	Rim	LGB 'light green-blue'	UU14	1423 n	9th century AD
GL0572	Closed	Neck C	_	Rim	IB 'ice-blue'	UU11	014	mid-7th to 8th century AD
GL2475	Closed	Flaring - straight	_	Rim	OG 'olive green'	UU14	1443	mid-7th to late-8th century AD

Table 5. 1

STUDIED MATERIAL FROM UNGUJA UKUU

GL Number	Form	Type	Decoration	ID	Colour	Trench	Context	Date
GL2689	Semi-open	Flaring - bevelled	_	Rim	LGB 'light green-blue'	UU14	1433	mid-7th to late-8th century AD
GL1633	Semi-open	Flaring - bevelled	_	Rim	IB 'ice-blue'	UU14	1406f	9th century AD
GL3255	Closed	Flaring - straight	_	Rim	LGB 'light green-blue'	UU15	1556N	mid-7th to 9th century AD
GL0657	Push-up	5	_	Base	OG 'olive green'	UU11	016	mid-7th to 8th century AD
GL2293	Push-up	Edge of push-up	_	Base	OG 'olive green'	UU14	1431	mid-7th to 8th century AD
GL0077	Push-up	Edge of push-up	_	Base	LGB 'light green-blue'	UU10	004	8th-9th century AD
GL2715	Push-up	4	_	Base	OG 'olive green'	UU14	1436 w/s	mid-7th to late-8th century AD
GL1014	Push-up	6	_	Base	IB 'ice-blue'	UU14	1404e	9th century AD
GL0659	Push-up	3	_	Base	OG 'olive green'	UU11	016	mid-7th to 8th century AD
GL2290	Push-up	5	_	Base	IB 'ice-blue'	UU14	1431	mid-7th to late-8th century AD
GL1046	Ring base	Folded ring-base	_	Base	IB 'ice-blue'	UU14	1404e	9th century AD
GL1626	Ring base	Folded ring-base	_	Base	CL 'colourless'	UU14	1406f	9th century AD
GL1044	Ring base	Folded ring-base	_	Base	IB 'ice-blue'	UU14	1404e	9th century AD
GL0500	Ring base	Applied ring-base	_	Base	IB 'ice-blue'	UU11	010	mid-7th to 8th century AD

Table 5. 1

STUDIED MATERIAL FROM UNGUJA UKUU

GL Number	Form	Type	Decoration	ID	Colour	Trench	Context	Date
GL2478	Open	Triangular-beaked rim	_	Rim	LGB 'light green-blue'	UU14	1443	mid-7th to late-8th century AD
GL1950	Open	Triangular-beaked rim	_	Rim	CL 'colourless'	UU14	1406	9th century AD
GL2981	Open	Triangular-beaked rim	_	Rim	LGB 'light green-blue'	UU15	1511j	7th-9th century AD
GL3254	Open	Splayed rim	_	Rim	IB 'ice-blue'	UU15	1556N	mid-7th to 9th century AD
GL2616	Open	Rolled-in rim	_	Rim	IB 'ice-blue'	UU14	1408g	9th century AD
GL2657	Closed	Ribbed – narrow	_	Rim	IB 'ice-blue'	UU14	1418	9th century AD
GL0949	Closed	Ribbed – narrow	_	Rim	IB 'ice-blue'	UU14	1412i	9th century AD
GL1638	Closed	Ribbed – narrow	_	Rim	OG 'olive green'	UU14	1406f	9th century AD
GL1637	Closed	Ribbed – narrow	_	Rim	IB 'ice-blue'	UU14	1406f	9th century AD
GL1750	Open	Plain – fine	_	Rim	OG 'olive green'	UU14	1403b	9th century AD
GL1853	Open	Plain – rounded	_	Rim	IB 'ice-blue'	UU14	1404e	9th century AD
GL1044	Ring base	Folded ring-base	_	Base	IB 'ice-blue'	UU14	1404e	9th century AD
GL0119	Undiagnostic	U	_	Body	LGB 'light green-blue'	UU10	004	8th-9th century AD
GL2723	Open	Plain – rounded	_	Rim	IB 'ice-blue'	UU14	1421	9th century AD

Table 5. 1

STUDIED MATERIAL FROM UNGUJA UKUU

GL Number	Form	Type	Decoration	ID	Colour	Trench	Context	Date
GL1618	Open	Plain – rounded	_	Rim	IB 'ice-blue'	UU14	1406f	9th century AD
GL0079	Open	Plain – rounded	_	Rim	IB 'ice-blue'	UU10	004	8th-9th century AD
GL1747	Open	Plain – rounded	_	Rim	IB 'ice-blue'	UU14	1403b	9th century AD
GL1030	Open	Plain – rounded	_	Rim	IB 'ice-blue'	UU14	1404e	9th century AD
GL1620	Open	Plain – rounded	_	Rim	IB 'ice-blue'	UU14	1406f	9th century AD
GL2522	Open	Plain – fine	_	Rim	IB 'ice-blue'	UU14	1418L	9th century AD
GL1750	Open	Plain – fine	_	Rim	OG 'olive green'	UU14	1403b	9th century AD
GL2403	Open	Plain – fine	_	Rim	IB 'ice-blue'	UU14	1414 w/s	9th century AD
GL0190	Open	Inwards-folded rim	_	Rim	IB 'ice-blue'	UU10	006	8th-9th century AD
GL2450	Open	Inwards-folded rim	_	Rim	LGB 'light green-blue'	UU14	1446	mid-7th to late-8th century AD
GL2097	Closed	Folded and flattened rim	_	Rim	LGB 'light green-blue'	UU14	1423n	9th century AD
GL1339	Closed	Folded and flattened rim	_	Rim	TQ	UU14	1404d	9th century AD
GL2978	Closed	Folded and flattened rim	_	Rim	LGB 'light green-blue'	UU15	1511j	7th-9th century AD

Table 5. 1

STUDIED MATERIAL FROM UNGUJA UKUU

GL Number	Form	Type	Decoration	ID	Colour	Trench	Context	Date
GL0155	Open	Stepped rim	_	Rim	OG 'olive green'	UU10	005	8th-9th century AD
GL3450	Open	Stepped rim	_	Rim	CL 'colourless'	UU15	1551L	mid-7th to 9th century AD
GL0040	Open	Stepped rim	_	Rim	BL 'blue'	UU10	003	8th-9th century AD
GL0154	Open	Stepped rim	_	Rim	LGB 'light green-blue'	UU10	005	8th-9th century AD
GL0038	Open	Stepped rim	_	Rim	OG 'olive green'	UU10	002	8th-9th century AD
GL3449	Open	Stepped rim	_	Rim	CL 'colourless'	UU15	1551L	mid-7th to 9th century AD
GL0635	Open	Stepped rim	_	Rim	OG 'olive green'	UU11	014	mid-7th to 8th century AD
GL0943	Open	Stepped rim	_	Rim	CL 'colourless'	UU14	1412i	9th century AD
GL1029	Open	Stepped rim	_	Rim	IB 'ice-blue'	UU14	1404e	9th century AD
GL2677	Open	Plate	_	Base	BL 'blue'	UU14	1433	mid-7th to late-8th century AD
GL2325	Open	Plate	_	Base	IB 'ice-blue'	UU14	1418 W/S	9th century AD
GL2147	Open	Plate	Tooled	Rim	TQ	UU14	1436	mid-7th to late-8th century AD
GL1741	Open	Plain – thick	_	Rim	LGB 'light green-blue'	UU14	1403b	mid-7th to late-8th century AD

Table 5. 1

STUDIED MATERIAL FROM UNGUJA UKUU

GL Number	Form	Type	Decoration	ID	Colour	Trench	Context	Date
GL0911	Open	Plain – thick	_	Rim	CL 'colourless'	UU13	006	7th-9th century AD
GL2980	Open	Plain – thick	_	Rim	OG 'olive green'	UU15	1511j	7th-9th century AD
GL2580	Undiagnostic	U	_	Body	IB 'ice-blue'	UU14	1428 W/S	mid-7th to late-8th century AD
GL2857	Closed	Flaring - wide-mouthed	_	Rim	IB 'ice-blue'	UU14	1440	mid-7th to late-8th century AD
GL3387	Closed	Flaring - wide-mouthed	_	Rim	OG 'olive green'	UU15	1511K	7th-9th century AD
GL1343	Closed	Miniature jar	_	Rim	IB 'ice-blue'	UU14	1404d	9th century AD
GL1770	Application	Applied trail	Applied (trail)	Misc	OG 'olive green'	UU14	1403b	9th century AD
GL0717	Undiagnostic	U	Pinched	Body	IB 'ice-blue'	UU11	017	mid-7th to 8th century AD
GL0802	Application	Applied trail	Applied (trail)	Misc	TQ	UU11	017	mid-7th to 8th century AD
GL2412	Application	Applied trail	Applied (trail)	Misc	BL 'blue'	UU14	1440	mid-7th to late-8th century AD
GL2455	Application	Foot	Applied (foot)	Misc	IB 'ice-blue'	UU14	1446	mid-7th to late-8th century AD
GL3338	Open	Flaring-sided vessel	_	Rim	OG 'olive green'	UU15	1551M	mid-7th to 9th century AD

GL3386	Closed	Flaring - rolled-in rim		Rim	LGB 'light green-blue'	UU15	1511K	7th-9th century AD
GL3198	Closed	Flaring - rolled-in rim		Rim	LGB 'light green-blue'	UU15	1557o	mid-7th to 9th century AD
GL0757	Flat	Applied pad		Base	OG 'olive green'	UU11	017	mid-7th to 8th century AD
GL0984	Flat	Flat to rounded		Base	IB 'ice-blue'	UU14	1412h	9th century AD

Table 5. 2

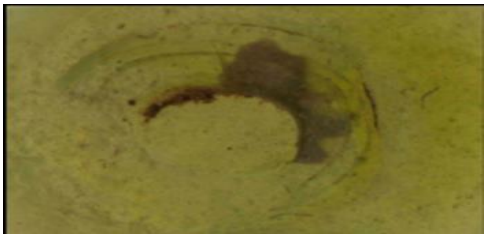
Basic system of colour identification proposed by Blair (Blair,2016:55).



LGB 'Light green-blue' glass



EG 'Bright emerald green' glass



OG 'Olive green' glass



BL 'Blue' glass



TQ 'Turquoise' glass



IB 'Ice-blue' glass



CL 'Colourless' glass

The majority of the glass samples was analysed using a standard Corning B. The Corning Archaeological Reference Glasses B is used as secondary standards for electron microprobe analysis in the Nanoscale and Microscale Center at the University of Nottingham. Natural Almandine ($Fe_3Al_2Si_3O_{12}$) was also used as a secondary standards to test the quality of analysis obtained from silicate minerals. The average of 20 random analysis points for EPMA and 15 for SEM are given below at **Table 5.3**, **Table 5.4** and **Table 5.5.** The analyzable area was 80x80 mm. The instrumentation is calibrating for a wide range of elements: F, Na, Mg, Al, Si, P,S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Nb, Mo, Cd, Su, Sb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Hf, Ta, W, Pb, Bi, Th and U. Sample of the Corning Glasses B was embedded in epoxy resin and vacuum-coated in carbon. Analyses were carried out using a JEOL JXA-8200 Electron Probe Microanalyser with attached 4 wavelength-dispersive spectrometers (detectable wavelengths of 0.087 to 9.3nm). Glass analysis in the the Nanoscale and Microscale Center at the University of Nottingham is to take area measurements 80 x 80mm, with magnification x40 to 300,000 (11mm WD), with an accelerating voltage of 20 kV at 20 nA probe currant. All elements 30 sec peak, 15 sec background counting time at each position.

Fifteen elements were measured (Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, SO_3, ClO, K_2O, CaO, TiO_2, MnO, FeO, Cr_2O_3, CuO, Zn). **Table 5.3** shows the recommended composition for the Corning B standard and the measured Corning B standard and the recommended composition for the Natural Almandine using EPMA in the Nanoscale and Microscale Center at the University of Nottingham. **Table 5.4** shows the recommended composition for the Corning B standard and the measured Corning B standard using SEM in the Nanoscale and Microscale Center at the University of Nottingham. **Table 5.5** shows the recommended composition for the Corning B standard and the measured Corning B standard using EPMA in the Environment, Earth and Ecosystem Sciences at the Open University. Finally, **Table 5.6** shows the recommended composition for the Corning B standard and the measured Corning B standard using EPMA in the Environment, Earth and Ecosystem Sciences at the 'The Open University'.

Table 5.3 The recommended composition for the Corning B standard compared to average analytical results (n= 20) and associated standard deviations using the electron microprobe (University of Nottingham).

20kV at 20 nA probe currant

All elements 30 sec peak, 15 sec background counting time at each position.

Measured Corning B						**Quoted Corning B**
Element	**Ave.**	**S.D.**	**Min.**	**Max.**		**Ave.**
SiO_2	67.55	3.20	55.35	70.24		61.55
Al_2O_3	3.80	1.36	2.11	5.06		4.36
Fe_2O_3	0.47	0.25	0.26	1.28		0.34
MnO	0.23	0.25	0.00	0.68		0.25
MgO	2.15	1.35	1.07	3.94		1.03
CaO	10.1	1.15	5.58	11.01		8.56
Na_2O	15.46	1.31	0.80	6.97		17.00
K_2O	1.56	0.63	0.92	2.38		1.00
TiO_2	0.19	0.15	0.00	0.49		0.09
Cr_2O_3	0.00	0.00	0.00	0.00		0.10
CuO	1.92	0.71	1.06	2.61		2.66
PO_2	0.66	0.31	0.30	0.96		0.82
SO_3	0.38	0.20	0.01	0.68		0.49
Cl	0.00	0.00	0.00	0.00		0.16
CrO	0.00	0.00	0.00	0.00		0.10
ZnO	0.12	0.10	0.00	0.24		0.19

Table 5.4 The recommended composition for the Corning B standard compared to average analytical results (n= 20) and associated standard deviations using SEM.

20kV at 20 nA probe currant

All elements 30 sec peak, 15 sec background counting time at each position.

Measured Corning B						**Quoted Corning B**
Element	**Ave.**	**S.D.**	**Min.**	**Max.**		**Ave.**
SiO_2	62.74	0.20	62.36	63.41		61.55
Al_2O_3	4.20	0.06	4.05	4.34		4.36
Fe_2O_3	0.29	0.06	0.00	0.41		0.34
MnO	0.25	0.06	0.00	0.36		0.25
MgO	0.97	0.05	0.88	1.05		1.03
CaO	8.75	0.11	8.57	9.01		8.56
Na_2O	17.11	0.17	16.82	17.49		17.00
K_2O	1.02	0.05	0.92	1.12		1.00
TiO_2	0.09	0.14	0.00	0.34		0.09
Cr_2O_3	0.07	0.09	0.00	0.19		0.10
CuO	2.84	0.09	2.61	3.09		2.66
PO_2	0.87	0.07	0.69	1.01		0.82
SO_3	0.74	0.07	0.59	0.85		0.49
Cl	0.00	0.00	0.00	0.00		0.16
CrO	0.00	0.00	0.00	0.00		0.10
ZnO	0.08	0.19	0.00	0.42		0.19

Table 5.5 The recommended composition for the Natural Almandine standard compared to average analytical results (n= 10) and associated standard deviations using the electron microprobe.

20kV at 20 nA probe currant

All elements 30 sec peak, 15 sec background counting time at each position.

Measured Natural Almandine						Quoted Natural Almandine
Element	Ave.	S.D.	Min.	Max.		Ave.
SiO_2	38.24	0.16	0.16	38.53		37.17
Al_2O_3	21.59	0.15	0.15	5.06		21.84
Fe_2O_3	35.57	0.23	0.23	35.93		35.63
MnO	0.00	0.00	0.00	0.00		0.26
MgO	2.46	0.08	0.08	2.63		2.43
CaO	4.00	0.16	0.16	4.36		4.29
Na_2O	0.03	0.04	0.00	0.15		0.00
K_2O	0.00	0.00	0.00	0.00		0.00
TiO_2	0.08	0.02	0.02	0.13		0.12
Cr_2O_3	0.01	0.01	0.00	0.02		0.07
CuO	0.00	0.01	0.00	0.02		0.00
PO_2	0.02	0.02	0.00	0.07		0.00
SO_3	0.00	0.00	0.00	0.01		0.00
Cl	0.01	0.01	0.00	0.02		0.00
CrO	0.01	0.01	0.00	0.05		0.07
ZnO	0.00	0.01	0.00	0.02		0.00

Table 5.6 The recommended composition for the Corning B standard compared to average analytical results (n= 20) and associated standard deviations using the electron microprobe (Open University).

20kV at 20 nA probe currant

All elements 30 sec peak, 15 sec background counting time at each position.

Measured Corning B						**Quoted Corning B**
Element	**Ave.**	**S.D.**	**Min.**	**Max.**		**Ave.**
SiO_2	61.32	0.91	59.78	63.03		61.55
Al_2O_3	3.60	0.71	2.42	4.11		4.36
Fe_2O_3	0.54	0.33	0.29	1.09		0.34
MnO	0.49	0.41	0.20	1.20		0.25
MgO	1.78	1.26	0.95	3.82		1.03
CaO	8.50	0.44	7.59	8.85		8.56
Na_2O	16.89	0.91	14.89	17.44		17.00
K_2O	1.53	0.84	0.96	2.94		1.00
TiO_2	0.12	0.04	0.06	0.23		0.09
Cr_2O_3	0.01	0.02	0.00	0.06		0.10
CuO	2.00	1.29	0.00	2.92		2.66
PO_2	0.69	0.27	0.25	1.18		0.82
SO_3	0.43	0.13	0.21	0.58		0.49
Cl	0.29	0.18	0.16	0.63		0.16
CrO	0.01	0.02	0.00	0.06		0.10
ZnO	0.16	0.06	0.05	0.23		0.19

CHAPTER 6

RESULTS

6.1 Chemical characterisation of Early Islamic vessels from Kadhima, Mughaira and Shiqaya

Major and minor elements for 160 glass fragments from Kadhima, Mughaira and Shiqaya (***Figure 6.1.1***, Blair,Ulrich,2013:45) were analysed by an electron microanalysis (EPMA) and scanning electron microscopy (SEM) to determine the sources of the glass and to reconstruct the trade. The operating conditions were a 20 kV accelerating potential. Major and minor analyses principally totalled between 97% to 103%. Primary standards were used. Accuracy and precision were improved with Corning B and Natural Almandine reference standards. For highly accurate quantification (major elements to a reliable two or more decimal places) SEM results were not used in this thesis. Results for the major and minor elements from the electron probe microanalysis are presented in **Table 6.1 (Appendix 2)** and from scanning electron microscopy in **Table 6.2 (Appendix 3)**. Results are reported as averages of three repeats. **Table 6.1 (Appendix 2)** and **Table 6.2 (Appendix 3)** provide mean concentrations accompanied by standard deviations (errors) of the oxides.

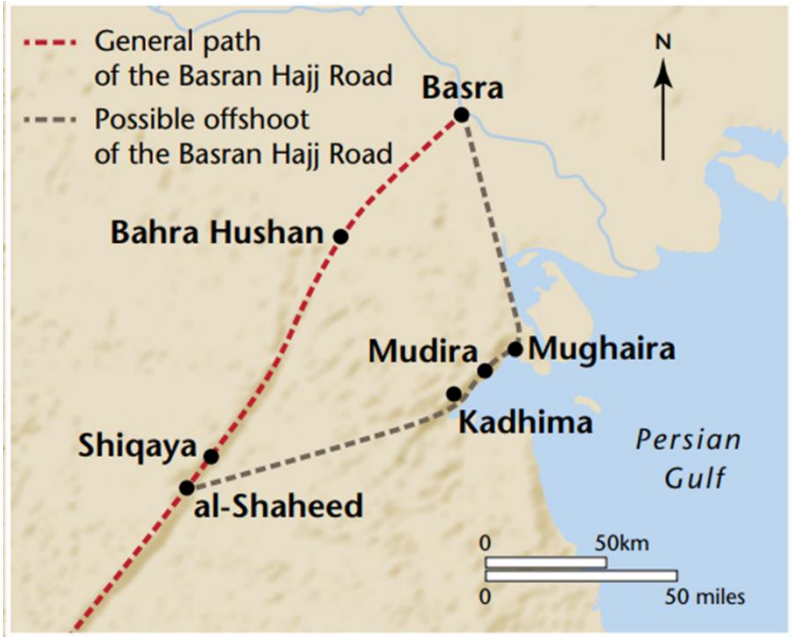


Figure 6.1.1: *Kadhima, Mughaira, Shiqaya in Kuwait mentioned in the thesis (created by Matt Bigg) (Blair,Ulrich,2013:45).*

Chemical analysis shows that all the samples (n=160) are soda-lime-silica glasses. But before elaborating on the glass types in more detail, it is necessary to comment on one fragment, GL957 (a closed and semi-open flaring straight mineral soda fragment). This fragment will not feature again in this study because its chemical characteristics are not identified clearly. **Table 6.3** illustrates how glass from Kadhima, Mughaira and Shiqaya may be divided, according to K_2O and MgO concentrations, into the two groups: high-K_2O, high-MgO glass and low- K_2O, low-MgO glass. The samples fall into two main categories that correspond to the use of two principle soda-rich fluxes available in the Islamic world-evaporitic minerals and plant ash (Freestone,2006:4). The distinction of the Kuwaiti glasses into two categories is illustrated in *Figure 6.1.2.*

Table 6.3 Major element compositions of selected soda-lime-silica glasses.

Oxide	***Glass Groups***	
	Type I Plant ash	***Type II Natron***
(n)	157	2
SiO_2	63.04	72.98
Al_2O_3	3.45	3.00
FeO	1.02	0.46
MnO	0.26	0
MgO	**4.26**	**0.55**
CaO	9.15	7.53
Na_2O	13.32	13.5
K_2O	**2.90**	**0.64**

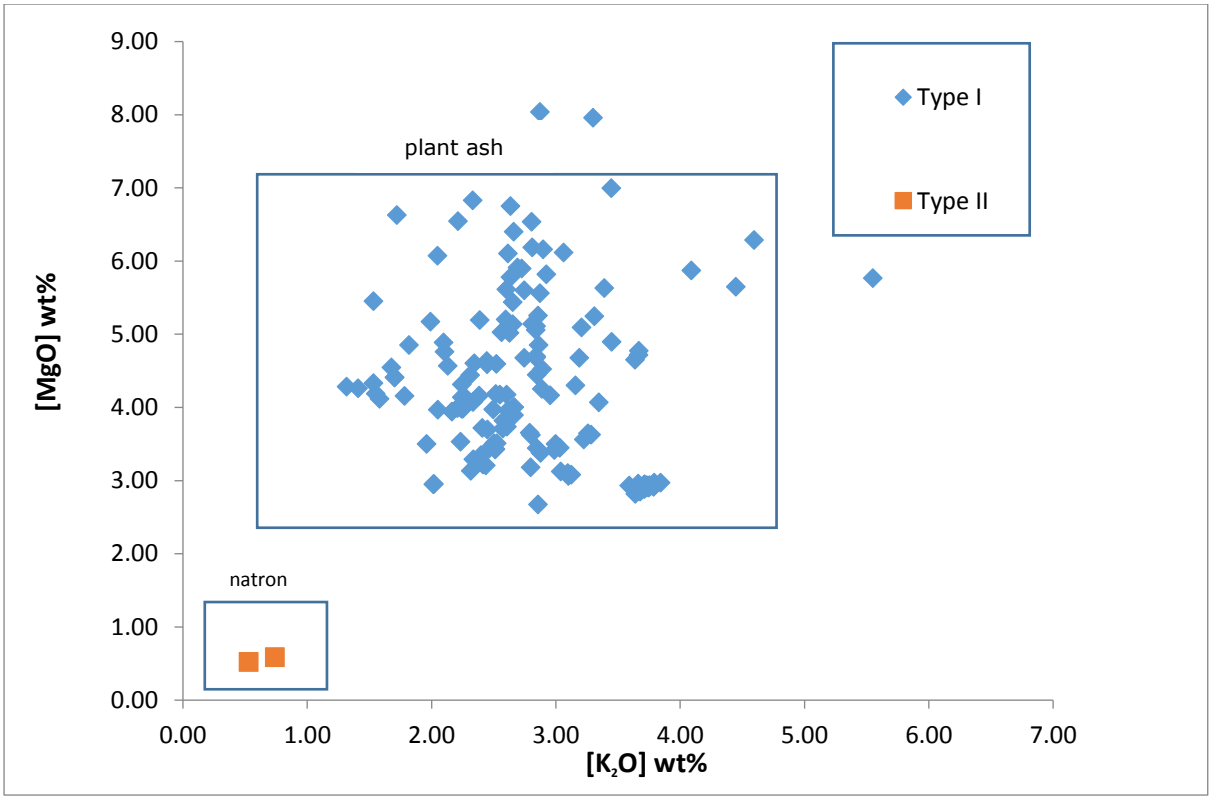


Figure 6.1.2: *K_2O versus MgO (wt%) for the glasses from Kadhima and Shiqaya presented in this study. Type I is plant ash glass; type II is a natron glass. Superimposed are oxide ranges for soda-lime-silica glasses of natron and plant-ash types according to Lilyquist & Brill (Lilyquist,Brill,1993).*

Figure 6.1.2 shows K_2O and MgO in a graph. Attention must be drawn to those oxides found as impurities in natron and plant ashes because they shed light on the distinction between the two types. The approximate ranges of these oxides are indicated in two boxes to show the differences between plant-ash and natron based glasses. Potassium and magnesium range in **Type I** plant-ash glasses are greater than 1.5% and in **Type II** 'natron' glasses are less than 1.5%. Sayre and Smith (Sayre,Smith,1961), cited in Freestone (Freestone,2006:4), have published a seminal paper with chemical analyses results of ancient glass which shows that high-K_2O, high-MgO glass with greater than about 1.5% of each of these oxides glass fall into one category and at the other category low- K_2O, low- MgO glass, typical with less than 1.5% of each oxide. The majority of the Kuwaiti glasses (n=157) are typical of soda-lime-silica composition with high-K_2O, high-MgO glass with greater than about 1.5%, made from a combination of ashed halophytic plants and sand. In the following, these glasses will be referred to as 'high-magnesia' or plant-ash glasses. Three samples are typical of soda-lime-silica composition with low-K_2O, low-MgO glass (average MgO

and K_2O <1 wt %) and will be termed as 'low-magnesia' or natron glasses. The mineral-soda type comprises a bottle neck, GL1798, and an open-flared side glass, GL1051. The average silica content is 72.98 % (SiO_2), 13.57% soda (Na_2O), and 7.53% lime (CaO). There is a general consensus that this specific type was made using evaporitic sodium carbonate (Freestone *et al.*, 2003). In more detail, on the basis of major oxides, through comparison of alumina and lime concentrations, it can be confirmed that GL1798 and GL1051 belong to the same group (Freestone *et al.*,2000;Freestone *et al.,*2002;Tal *et al.*,2004). Given that the lime and alumina concentrations are diagnostic of the silica source, the similarity of alumina and lime concentrations strongly imply that the mineral-soda glasses at Kadhima and Mughaira originated from the same silica source. This is not the case for the plant ash soda glass.

Deteriorated glass samples were prepared, as were the normal glass samples and were analysed by comparison to reference standards. The deteriorated samples were deeply polished in an attempt to get below the weathered surface and were analysed on the polished areas (***Figure 6.1.3***). According to soda levels (Na_2O), 32 soda-lime glasses (GL8, GL748, GL1242, GL1007,



Figure 6.1.3: *Nine heavily corroded fragments featuring a Na_2O concentration below 8%.*

GL299, GL1302, GL1419, GL854, GL1474, GL1009, GL1461, GL1844, GL584, GL1435, GL953, GL 398, GL1024, GL644, GL346, GL1649, GL644, GL634, GL1405,GL1415, GL1419, GL1397, GL1416, GL1392, GL14O3, GL1399, GL735, GL1396, GL1402) fall below 8% well below what was expected from the known early Islamic glassmaking. In the literature, there is evidence of an almost constant composition of early Islamic glasses featuring a Na_2O concentration above 8%. Experiments have shown that glasses with a Na_2O concentration below 8% have been weathered. The leaching process is the main reason for weathered surfaces. The understanding of the leaching process is difficult as this process is highly complex (Schreiner, 1991:255). Depending on the nature of the material used or the environment those samples exposed (to moist earth for centuries) an iridescent surface layer occurred altering the original state of the glasses (Schreiner,1991:255). The glass samples from the Kuwaiti Bay with a Na_2O concentration below 8% that are heavily corroded and slightly tinted in yellow-brown by the natural sand impurities cannot be compared with other Islamic glasses and therefore will not feature again in this thesis.

The interpretation of Kuwaiti glasses can be further corroborated by superimposing the data from Kadhima and Mughaira onto those of different production groups. Thus, low-magnesia or natron-based Kuwaiti glasses will be compared with ***Levantine I, Levantine II***, ***Egypt I***, ***Egypt II*** and ***a Levantine source***, made of glass. These findings are thoroughly published but it was decided to include a cursory summary of the data in **Table 6.4**, as it might prove useful to some readers. **Table 6.4** shows the major element compositions of low-magnesia or natron-based glasses from the above production groups. Plant-ash glass from Kadhima, Mughaira and Shiqaya is more complex and heterogeneous material than natron and this was something to be expected (Freestone,2002:20); hence plant-ash glasses will be compared with different plant-ash glasses from **Iran/Iraq**, **Syria**, **Egypt** and **Levantine coast**. Major and minor concentrations of high-magnesia glasses are shown in **Table 6.5.**

Table 6.4. Mean and standard deviations of the major and minor elements of the four known literature low-magnesia groups.

Oxide		Egypt I	Egypt II	Levantine I	Levantine II
SiO_2	M	70.05	67.85	71.60	76.20
	S.D.	1.21	1.90	1.64	1.22
Al_2O_3	M	4.05	2.19	3.03	3.32
	S.D	0.29	0.35	0.22	0.18
FeO	M	1.74	0.98	0.46	0.57
	S.D.	0.28	0.23	0.04	0.21
MnO	M	514 ppm	302 ppm	195 ppm	189 ppm
	S.D.	70	146	9	30
MgO	M	**0.93**	**0.58**	**0.64**	**0.52**
	S.D.	0.14	0.13	0.11	0.03
CaO	M	3.03	9.34	8.14	6.42
	S.D.	0.23	1.27	0.76	0.77
Na_2O	M	18.25	17.26	14.51	11.56
	S.D.	1.38		1.15	1.18
K_2O	M	**0.40**	**0.32**	**0.49**	**0.44**
	S.D.	**0.11**	**0.24**	**0.10**	**0.11**

Sources of data: Gratuze, Barrandon, 1990, Freestone,2006, Tal et al JGS, 2004, Phelps, 2016.

Table 6.5. Major and minor elements of high -magnesia groups.

Oxide	Iraq Sāmarrā	Iraq Ctesiphon	Iran Nishapur	Iran Sīrāf	Syria al-Raqqa	Syria Damascus	Levant Banias	Egypt Cairo
SiO_2 M	63.2	65.13	60.96	68.80	64.7	65.31	70.5	66.10
Al_2O_3 M	1.44	1.92	1.34	0.80	2.37	0.84	1.06	2.21
FeO M	0.40	0.73	0.41	0.44	1.28	0.29	0.40	0.78
MnO M	3.20	0.04	0.17	2.98	1.11	0.74	1.00	0.16
MgO M	**6.2**	**3.29**	**5.90**	**2.07**	**3.74**	**2.69**	**2.72**	**2.59**
CaO M	5.33	8.26	8.10	7.00	8.45	7.72	8.55	9.20
Na_2O M	15.2	14.31	17.43	13.5	13.91	12.27	12.5	14.10
K_2O M	**3.20**	**3.09**	**2.96**	**2.88**	**2.57**	**1.99**	**1.89**	**2.42**

Sources of data: Henderson, 1999, Freestone, 2006, Kato et al.,2010, Henderson et al., 2016, Swan et al., 2017.

6.2 Low-magnesia or natron based glass from Kadhima, Mughaira and Shiqaya

General chemical observation

The investigation presented here aims to identify the origins of the natron Kuwaiti glasses, a bottle neck, GL1798 (***Figure 6.2.1***), and an open-flared side glass, GL1051. Lime and alumina concentrations reflect those in the raw material will be used to reveal the place where the raw glass was made. It should be noted that lime and alumina concentrations can be used to provide an initial impression of glass groups (Freestone,2006:208). ***Figure 6.2.2*** compares two natron Kuwaiti glasses, with five commonly occurring glass groups, ***Levantine I, Levantine II***, ***Egypt I***, ***Egypt II*** and ***a Levantine source***, from an early Islamic workshop in Tel Aviv (Freestone,2006:208;Freestone *et al.*,2015). It should be noted that ***Egypt I*** and ***Egypt II*** are compositionally distinct from Levantine glass. Each group is assumed to relate to a primary production centre. Analyses of glasses in previous studies have shown that these groupings are largely a reflection of calcium carbonate and feldspar minerals in the sand (Freestone,2006:208).



Figure 6.2.1.*: Low-magnesia bottle neck uncovered in a large, three-roomed stone-walled structure, central room during excavations in Mughaira.*

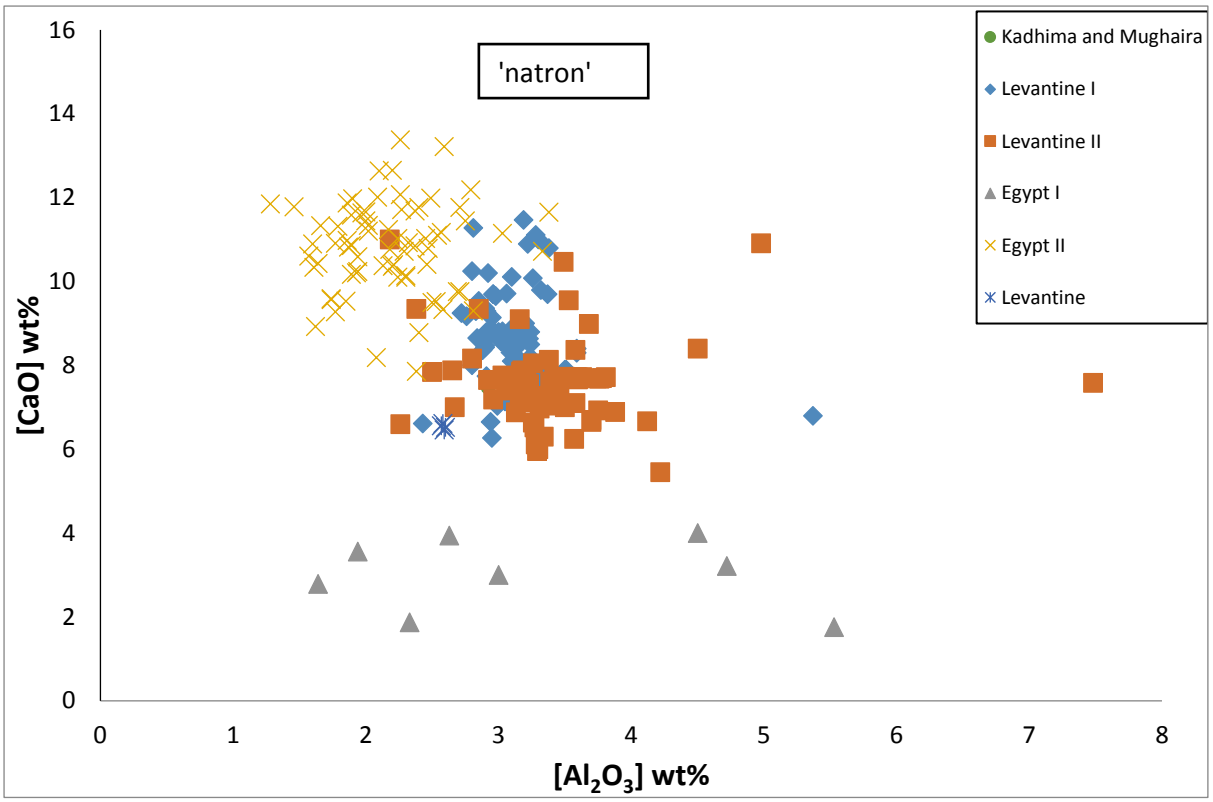


Figure 6.2.2.: *Kadhima and Mughaira 'glasses in comparison with contemporary glass production groups. The lime and alumina concentrations of the two early Islamic samples (orange diamonds) from Kadhima and Mughaira were compared with the data of contemporary glass types; Levantine I glass from Apollonia, Dor, Jalame, Ramla, al Raqqa, Bet Shean and Unguja Ukuu; Levantine II glass from Bet Eli'ezer, Tel Aviv, Raya, monastery of Wadi al-Tur; Unknown source from chunk and vessels found at an early Islamic workshop in Tel Aviv; Egypt I from Wadi al-Natrun and Egypt II from Fusṭāṭ , El-Ashmunein and the monastery of Wadi al-Tur.*

The selected sites of the ***Levantine I*** group are: the late Byzantine secondary workshop at Ramla (South), Israel (Tal *et al.*,2008), the late Byzantine secondary workshop at Beth Shean (Freestone *et al.*,2003), the late Byzantine Apollonia-Arsuf, Israel (Freestone *et al.*, 2008), Dor (Freestone *et al.*,2000), Jalame (Brill,1988) and al-Raqqa (Henderson,1999). The selected sites of the ***Levantine II*** group are Bet Eli'ezer (Freestone *et al.*,2000), Tel Aviv (Freestone *et al.*,2015), Raya (Kato *et al.*,2009), the monastery of Wadi al-Tur (Kato *et al.*, 2009) and unknown source of glass from an early Islamic workshop in Tel Aviv (Freestone et al.,2015). The selected site of the ***Egypt I*** group is Wadi al-Natrun (Nenna *et al.*,2005) and from ***Egypt II*** the secondary workshops at Fusṭāṭ (Shindo,2000), the early Islamic workshop in Tel Aviv (Freestone *et al.*,2015), El-Ashmunein (Bimson,Freestone,1985), Raya (Kato *et al.*,2009) and the monastery of Wadi al-Tur (Kato *et al.*,2009).

Figure 6.2.2 shows natron glasses from Kadhima and Mughaira overlapping between ***Levantine I*** and ***Levantine II*** types, although they more closely fit the oxide profile for ***Levantine I*** glasses. For the moment, through previous excavations and chemical analyses it has been proven that ***Levantine I*** glass was produced using coastal sands that contain the right concentrations of quartz and calcite, so that they could be mixed with soda (probably from the Wadi-Natrun in Egypt) to produce a blue-green glass (Freestone *et al.*,2003;Freestone *et al.*,2008). It is especially interesting that the two natron glass samples, defined as ***Type I***, seem to be associated with Levantine natron glasses made in the eastern Mediterranean, with alumina at about 3 wt %, along with several other types identified in the central and eastern Mediterranean for the period in question. Through trace element analysis, Freestone and his colleagues show that the specific type of glass was produced using Eastern Mediterranean beach sand with high strontium levels, and this reflects the presence of fresh shell in the beach sand (Freestone *et al.*,2000). It is characteristic that this shell is typically made up of $CaCO_3$ and has a much higher capacity to incorporate strontium than calcite (Freestone *et al.*,2000). In order to attempt to assign Kuwaiti glasses exclusively to ***Levantine I*** and ***Levantine II*** types, it was essential to compare more than two elements. Therefore, a detailed comparison of the individual samples follows, as reported in **Table 6.6.** Here each element is considered and compared separately (**Table 6.6**). The distinction between ***Levantine I*** and ***Levantine II*** was underscored previously by Freestone and his colleagues (Freestone *et al.*,2000).

Table 6.6 indicates that ***Type I*** glasses from Kadhima and Mughaira are distinct from the ***Levantine II*** group, which is associated with the large-scale manufacturing installations at Bet Eli'ezer near Hadera in Israel. Since sodium and lime contents are lower and concurrently lower are silica concentrations, the very fact indicates a different silica source despite the common use of local coastal sand (Freestone,Gorin-Rosen,1999;Freestone *et al.*,2002a; 2003). Of course, the reduction in sodium content, just 12.1% in the Bet Eliezer glasses and 13% in the Kadhima and Mughaira glasses, suggests a relative reduction of natron content (20-25%) in the batch that could allow for the production of more glass using the same quantity of alkali (**Table 5.6**, Freestone e*t al.*,2000). For further investigation, ***Type I*** data is superimposed with data from sites dated to the same period. For example, sites such as Apollonia-Arsuf, Ramla, Dor, Tyre, Jalame, Bet Eli'ezer, Shean, Raya, Tel el-Ashmunein, al-Raqqa and Unguja Ukuu (Zanzibar) can be considered appropriate for this comparison. The plot of alumina oxide versus lime, ***Figure 6.2.3***, shows the comparison.

Table 6.6 Major element compositions of selected soda-lime-silica glasses.

Oxide	GL1798 Type I	GL1051 Type I	Levantine II	Levantine I
Place	**Mughaira**	**Mughaira**	**Apollonia**	**Bet Eli'ezer**
Date	**mid-7 -8th C AD**	**mid-7-8th C AD**	**6-7th C AD**	**7-8th C AD**
SiO_2	72.7	73.3	70.3	74.9
Al_2O_3	3.08	2.92	3.24	3.32
FeO	0.51	0.52	0.54	0.52
MnO	0	0	0	<0.1
MgO	0.59	0.52	0.53	0.63
CaO	7.6	7.5	8.6	7.16
Na_2O	13.4	13.8	15.0	12.1
K_2O	0.74	0.53	0.79	0.46

Sources of data: Freestone, 2006, Tal et al, 2004.

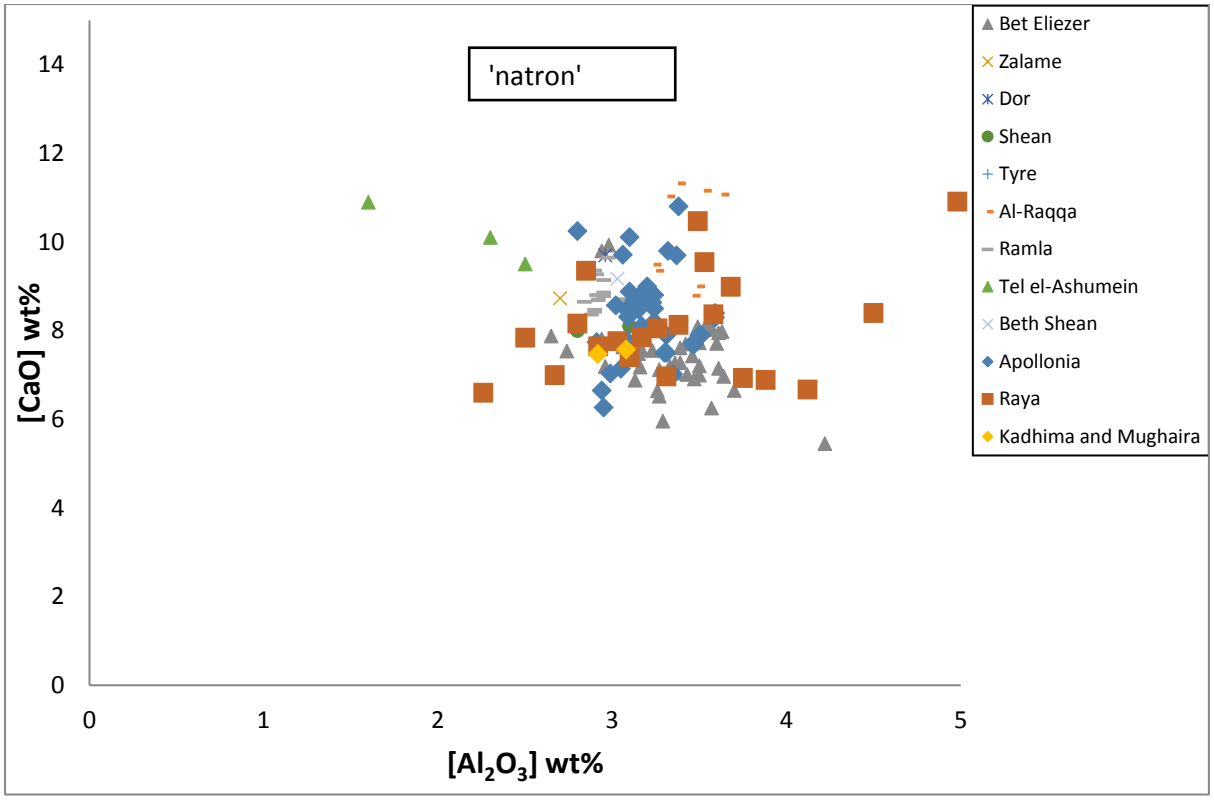


Figure 6.2.3: *The lime and alumina concentrations of the early Islamic samples from Kadhima and Mughaira (blue diamonds) were compared with the data of early Islamic sites; glass from Apollonia, Bet Eli'ezer, Jalame, Dor, Shean, Ramla, al Raqqa, Bet Shean, Tyre, Raya and Tel el-Ashmunein.*

Figure 6.2.3 shows that Kadhima and Mughaira glasses share similarities with the glasses from ***Levantine I*** excavated at Apollonia-Arsuf, dating between the 6th and 8th centuries AD. The plot of alumina oxide versus lime shows a clear separation of the Kuwaiti glasses and Tel el-Ashumein, al-Raqqa and Bet Eliezer glasses. More analytically, the two Kuwaiti samples have about 3% Al_2O_3 lower than Bet Eliezer and al-Raqqa and about 7.5% CaO higher than Bet Eliezer and lower than al-Raqqa and Ramla. In terms of lime versus alumina the Kuwaiti samples data plot close to the Apollonia-Arsuf data; this support the view that are compositionally closer to ***Levantine I*** Apollonia-Arsuf glasses. As to the relationship between the natron bottle neck and the open-flared side glass with different natron types and forms of vessels and decoration ***Figure 6.2.4*** and ***Figure 6.2.5*** will compare the Kuwaiti samples with low-magnesia pinched, trailed and applied decorated vessels uncovered from the excavations at Unguja Ukuu, Zanzibar and lustre-stained vessels uncovered from the excavations at Raya.

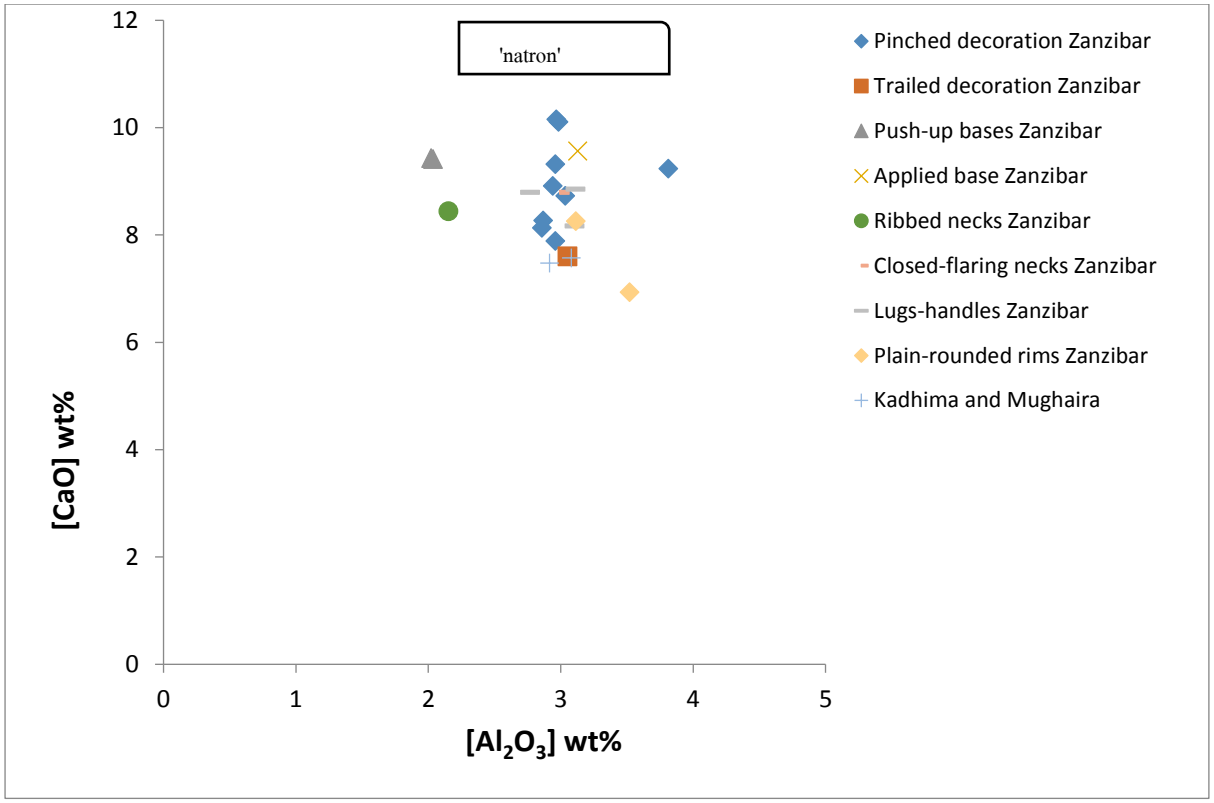


Figure 6.2.4: *Kadhima and Mughaira natron glasses in comparison with early Islamic glass vessels of different type, form and decoration from Unguja Ukuu, Zanzibar.*

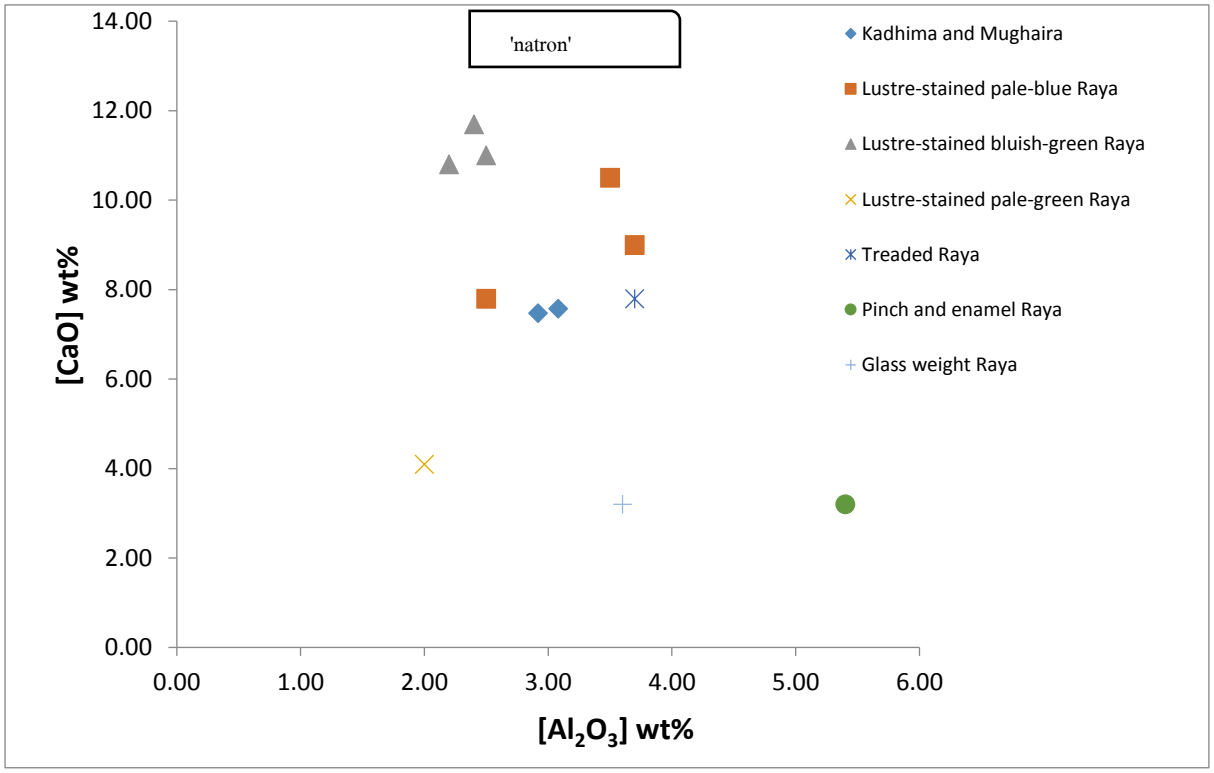


Figure 6.2.5: *Kadhima and Mughaira natron glasses in comparison with early Islamic glass vessels of different type, form and decoration from Raya.*

The lime level in the Kuwaiti glasses is noticeably lower (7.5%) than the Unguja Ukuu glasses. *Figure 6.2.4* shows that only one Kuwaiti glass plotted lower in the graph due to the low CaO content. Nevertheless, a trailed decorated fragment from Unguja Ukuu is closest to the mean values of CaO and K_2O in Kuwaiti glasses. Lime content around 8-9% means sand suitable for the production of glass. According to Freestone, this CaO (8-9%) content is around the level required to produce a workable and stable glass (Freestone,2006:10). Similar lime content of sand in the Kuwaiti glasses has been recognized closed to the mouth of the River Belus and in the eastern Mediterranean region (Apollonia-Arsuf, Bet Eli'ezer, Hadera and Egypt (Freestone,2002:10). Besides Unguja Ukuu glasses, there were other interesting natron glass objects from Raya. The plot of alumina versus lime in *Figure 6.2.5* shows that the lime values of the Kuwaiti glasses vary considerably from the lustre-stained bluish-green, lustre-stained pale green and lustre-stained pale blue from Raya. Nevertheless, the lime values of the Kuwaiti glasses appear to be close, but not identical, to a lustre-stained pale-blue from Raya. At present, therefore, it must be concluded that the relationship of the Kuwaiti natron glasses to the lustre-stained glass from Raya is unclear.

6.3 Plant ash glass from Kadhima, Mughaira and Shiqaya

General chemical observation

By far the majority (n=123) of glasses from Kadhima, Mughaira and Shiqaya that are discussed here were found to be plant ash glasses. While all the glasses conform to a plant-ash soda formulation, there is variability in the major and minor oxides. This is to be expected, given that the glasses were made in different locations (Brill,2005:67). The variability must have resulted from four sources. The following discussion deals with the comparisons of 123 samples of flux with plant ash; the comparisons presented in ***Figures 6.3.1*** to ***6.3.6*** show that the samples, in terms of major and minor elements (alumina, lime, sodium, magnesium, potassium and iron concentrations), fall into four relatively discrete compositional groups, designated here as ***Group I***, ***Group II***, ***Group III*** and ***Group IV***. Table 6.7 shows the average concentrations of each plant-ash group. While all the glasses discussed here conform to a plant-ash soda formulation, there is variability in the major and minor oxides. This is to be expected, given that the glasses were made in different locations (Brill,2005:67).

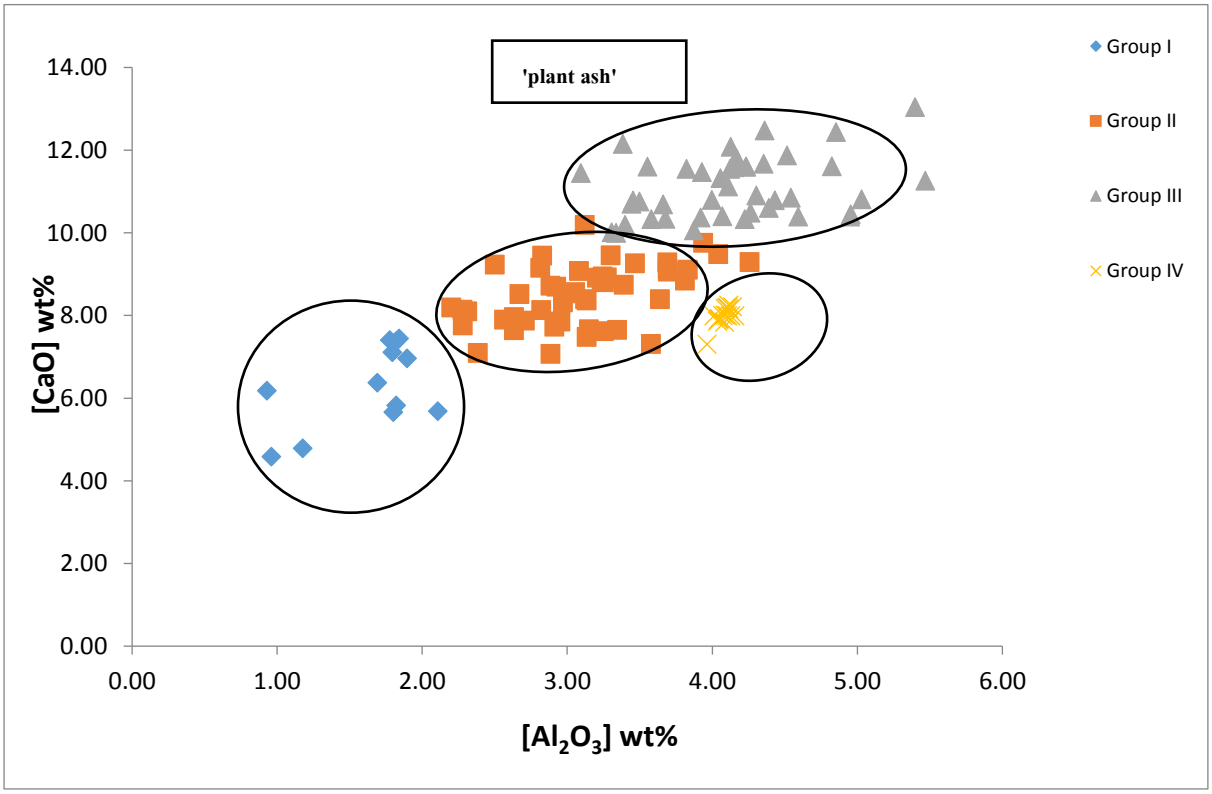


Figure 6.3.1: *Plot of lime versus alumina for all analyzed plant ash glasses from Kadhima, Mughaira and Shiqaya.*

Table 6.7. Major element compositions of plant-ash soda-lime-silica glasses.

Oxide	Group I	Group II	Group III	Group IV
(n)	1 2	48	45	18
SiO_2	65.4	62.88	61.15	66.49
St.Dev	3.28	1.48	2.13	1.30
Al_2O_3	**1.64**	**3.00**	**4.15**	**4.08**
St.Dev.	**0.39**	**0.66**	**0.80**	**0.05**
FeO	0.66	0.98	1.25	0.91
	0.19	0.21	0.22	0.04
MnO	0.66	0.64	0.32	4.17
St.Dev.	0.80	0.74	0.16	1.05
MgO	**4.97**	**4.04**	**4.84**	**3.00**
St.Dev.	**1.06**	**1.05**	**0.80**	**0.40**
CaO	**6.29**	**8.5**	**11.11**	**8.00**
St.Dev.	**1.00**	**0.73**	**0.74**	**0.21**
Na_2O	15.42	14.95	12.74	8.85
St.Dev.	0.91	1.63	3.07	2.31
K_2O	**3.15**	**2.72**	**2.72**	**3.65**
St.Dev.	**0.71**	**0.62**	**2.62**	**0.33**

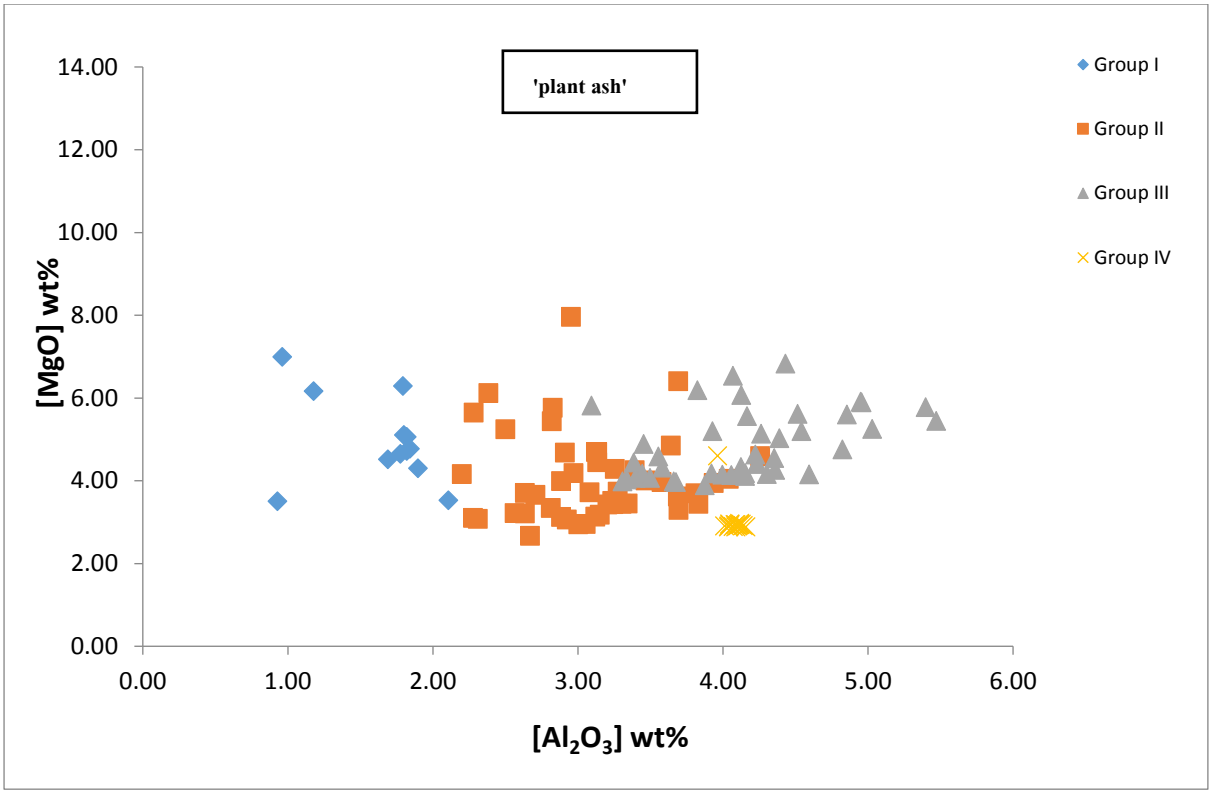


Figure 6.3.2: *Plot of alumina versus magnesium for all analyzed plant ash glasses from Kadhima, Mughaira and Shiqaya.*

A number of bi-plots for both 2 sets of oxides were created for major elements results. ***Figures 6.3.1-6.3.3*** provided here are considered to be the most instructive for the thesis as their bi-plots indicate clear differences in composition that correspond to different origins of the glass groups.

For the plant-ash Kuwaiti glasses, as for other Islamic plant-ash glasses, alumina, lime and magnesium are found to be the most effective discriminators (***Figures 6.3.1-6.3.3***). ***Figures 6.3.1 --6.3.4*** show differences that reflect differences in raw materials and may be used to provide an impression of glass groups (Freestone,2006:208). In ***Figure 6.3.1,*** the ellipse marked '***Group I***' contains 12 samples having different chemical composition with less than 2% Al_2O_3 and less than 7% CaO from the other groups, ***Group II*** that having 3% Al_2O_3 and less than 8% CaO, ***Group III*** that having more than 3% Al_2O_3 (70% of the samples has more than 4% Al_2O_3) and 11% CaO and finally ***Group IV*** that having around 4% Al_2O_3 and less than 8 %CaO. ***Figure 6.3.1*** is the first graph to show clear evidence of the distinction between glasses found in Kuwaiti Bay. The alumina concentration of ***Group III*** more than 4% is fundamentally distinctive. A survey of the literature reveals that this alumina concentration is unmatched by any data we know of other early Islamic sites. It can be seen in ***Figures 6.3.1*** that the lime concentration of ***Group III*** more

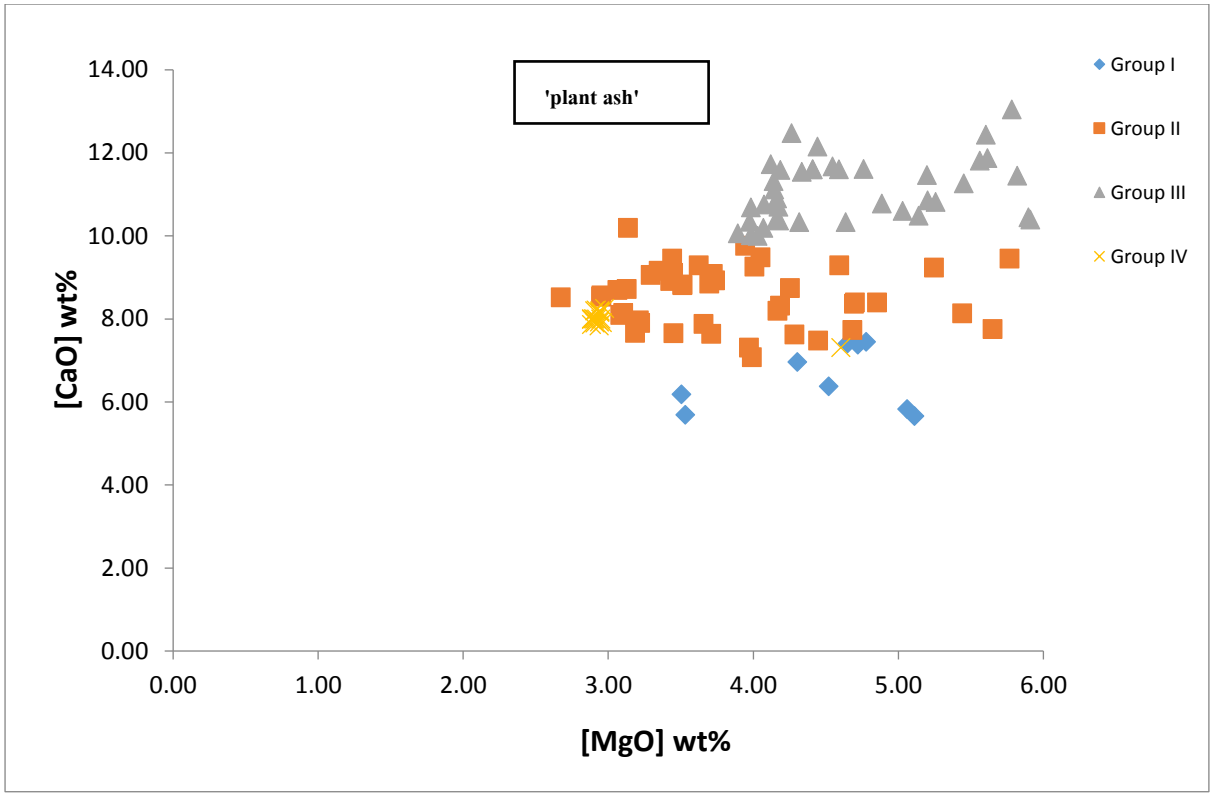


Figure 6.3.3: *Plot of magnesium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira and Shiqaya.*

than 10% is also distinctive. ***Figure 6.3.1*** indicates that ***Group I, Group II*** and ***Group III*** have different lime concentrations. According to ***Figure 6.3.2,*** the MgO concentrations are very similar. It can be seen in ***Figure 6.3.2*** that ***Group IV*** and ***Group II*** are similar having lower magnesium content.

Figure 6.3.3 is a bi-plot of weight % of magnesium versus lime showing that ***Group I*** glasses contain less than 8% lime, ***Group II*** and ***Group IV*** around 8% and ***Group III*** contain greater than 10% lime. Previous chemical and trace element analysis has increased our awareness and knowledge of the types of glass showing that glass found and apparently made in Iran and Iraq has the lowest Al_2O_3 and CaO levels as those from ***Group I*** while Syrian and Levantine glass has high around 8-10% as those from ***Group II*** and ***Group IV*** .***Figure 6.3.3*** shows that ***Group III*** has the highest CaO levels. Trace element analysis on Middle Eastern plant ash Islamic glasses, conducted by Henderson and his colleagues (Henderson *et al.*,2016), and isotopic analysis conducted by Freestone and his colleagues (Freestone et al.,2009:70), proved a very helpful approach, providing meaningful regional compositional groups. Through their analysis, it has been shown

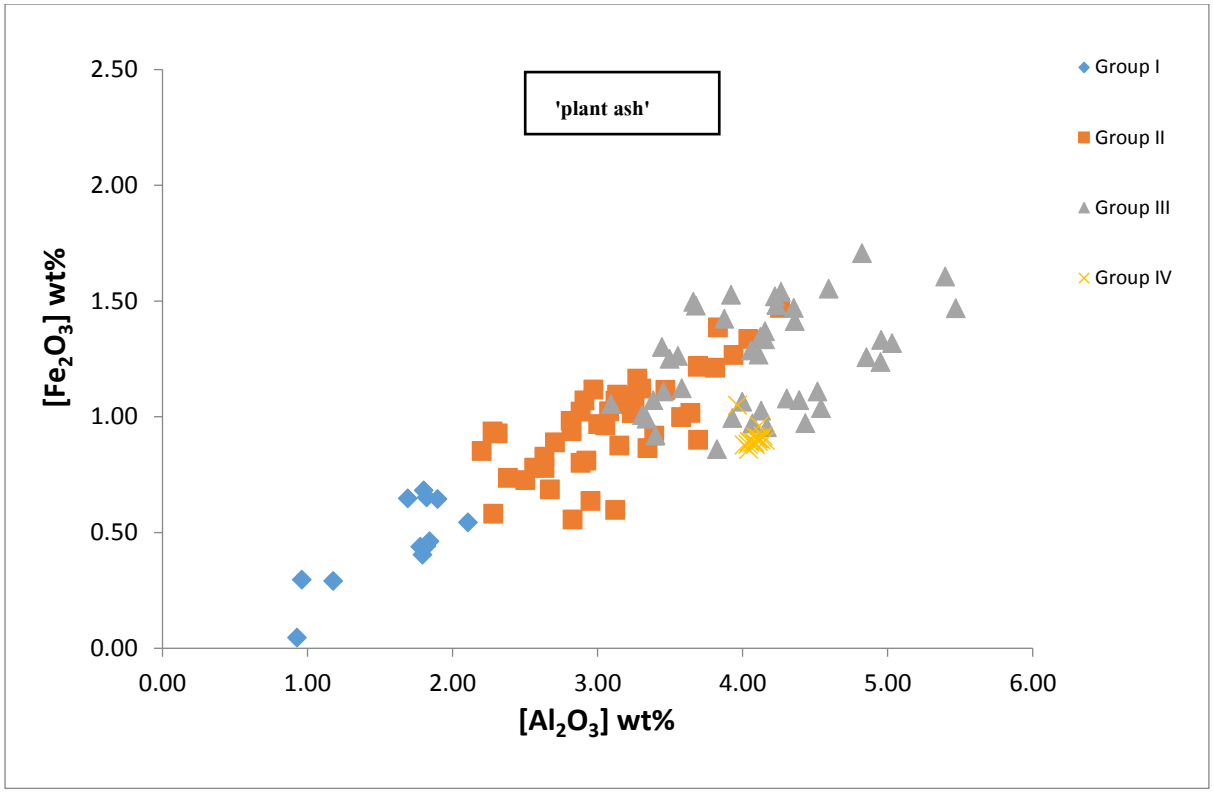


Figure 6.3.4: Plot of alumina versus iron for all analyzed plant ash glasses from Kadhima, Mughaira and Shiqaya.

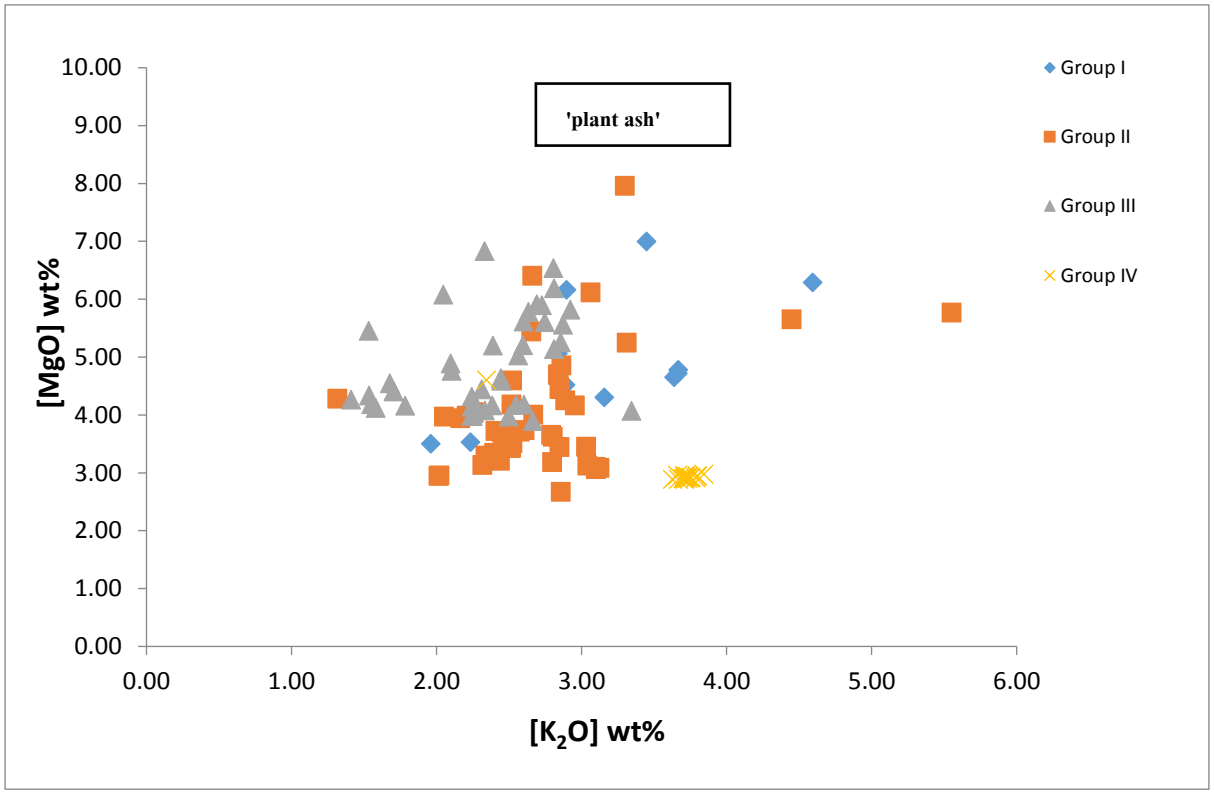


Figure 6.3.5: Plot of potassium versus magnesium for all analyzed plant ash glasses from Kadhima, Mughaira and Shiqaya.

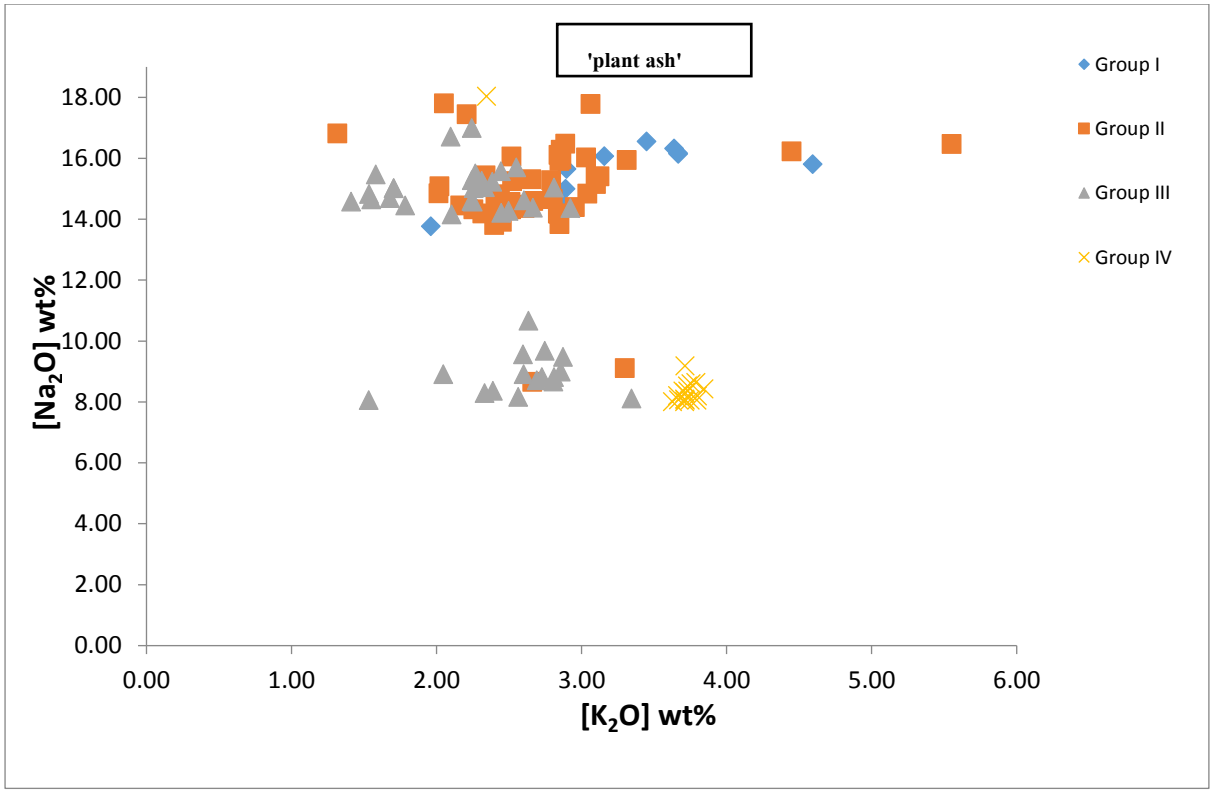


Figure 6.3.6: *Plot of potassium versus sodium for all analyzed plant ash glasses from Kadhima, Mughaira and Shiqaya.*

that plant ash glasses made in the Levant have low alumina (below 2%) and high lime (above 9%) levels. These were easily distinguishable from the Iran/Iraq glasses containing the lowest CaO (below 7%), but not as distinguishable from the northern Syrian glasses containing less than 9% CaO (Freestone,2002:70;Henderson *et al.*,2016:138). Here, more trace element analysis may be needed because alumina, lime and magnesium are not always enough to provide meaningful compositional groupings (Freestone,2002:70;Degryse *et al.*,2010:87). ***Figures 6.3.4--6.3.6*** show some comparisons.

Figure 6.3.5 indicates that the magnesium ranges in ***Group I*** and ***Group III*** are elevated more than 4% than ***Group II*** and ***Group IV***, which are below 4%. Previous chemical and trace element analysis show that Syrian and Levantine glass has the lowest MgO levels as those found in ***Group II*** and ***Group IV*** and Iran and Iraq glass has the highest MgO levels as those found in ***Group I*** and ***Group III*** (Henderson *et al.*,2016:138). ***Figure 6.3.4***, a plot of iron versus alumina shows a clear distinction between ***Group I*** that has the lowest Al_2O and clearly significantly less iron than ***Group II***, ***Group III*** and ***Group IV*** that has the highest iron content. ***Figures 6.3.5 --6.3.6*** indicate that potassium and especially sodium values as opposed the other elements are not

significant elements in the distinction of the groups and this is something to keep in mind.

A word finally about the variability in Kuwaiti glass compositions. The variability must have resulted from four sources. By comparing the samples from each group with samples from contemporary sites, it is possible to find very detailed information about the sources of glass from each group. However, another piece of information can also be gleaned from the data. When comparing glasses from different places, we can see the trade or exchange contacts between various civilizations. Plant ash vessels, as a trade item, reveal which regions participated in the glass trade system within the Persian Gulf throughout the early Islamic period. The broad geographical zone can be identified using a plot of Al_2O_3 versus CaO and CaO versus MgO.

Here, data from Kadhima, Mughaira and Shiqaya will be compared with data published by Robert Brill, Ian Freestone, Julian Henderson and their colleagues. The data reported derive from Sāmarrā (Iraq) (Henderson *et al.*,2016), Ctesiphon (Iraq) (Brill,2005;Henderson *et al.*,2016), Tell Umm Jirin (Iraq) (Brill,2005), Takht-i Sulaiman (Iran) (Brill,2005), Nishapur (Iran) (Brill,1995;Brill,1999;Wypysky,2015;Henderson *et al.*,2016),Sīrāf (Iran) (Brill,1999;Swan *et al.*,2017), al-Raqqa (Syria) (Henderson *et al.,*2004), Damascus (Syria) (Henderson *et al.*,2016), Khirbat al-Minya (Israel) (Henderson *et al.*,2016), Ramla (Israel) (Tal *et al.*,2008), Beirut (the Lebanon) (Henderson *et al.*,2016), Banias (the Lebanon) (Freestone *et al.*,2000,Freestone et al.,2003,Degryse *et al.*,2010), Bet She'arim, (the Lebanon) (Freestone, Gorin-Rosen,1999), Tyre (the Lebanon) (Degryse *et al.*,2010), Fūstat (Egypt) (Brill,1999, Henderson et al.2016) and finally Unguja Ukuu, Zanzibar (Africa).

6.3.1 Group I high-magnesia or plant-ash glass

We now come to what designated as ***Group I*** in this study comprising 12 vessels, having relatively the lowest concentrations of alumina, ranges from 0.93 to 2.11% and lime from 4.58 to 7.45% (**Table 6.8**). The overall picture is that levels of lime below 8% and alumina below 2% assume an Iraqi or Iranian source(Henderson *et al*,2016:138). Using this as a guideline, 12 samples containing the above levels of lime and alumina will be compared, as ***Figures 6.3.1.1-6.3.1.3*** show, with samples of similar compositional types from Iraq and from Iran dating back to the Sasanian or early Islamic time. It is presumed that the Iraqi and Iranian samples will be closely related. According to Robert Brill, when comparing glasses from different archaeological sites, there has to be agreement across more than one plot before any conclusions can be drawn (Brill,2005:70). For this reason, three plots were used. Before proceeding to the results, it should be mentioned that ***Group I*** comprises four closed ribbed necks (GL879, GL923, GL692, GL1264), three open-stepped rims (GL1364, GL1329, GL1356), a closed and semi-open flared straight vessel (GL 15), an inwardly-open folded rim (GL85), an open-plain fine vessel (GL1003) and finally a closed-plain vertical vessel (GL1848).

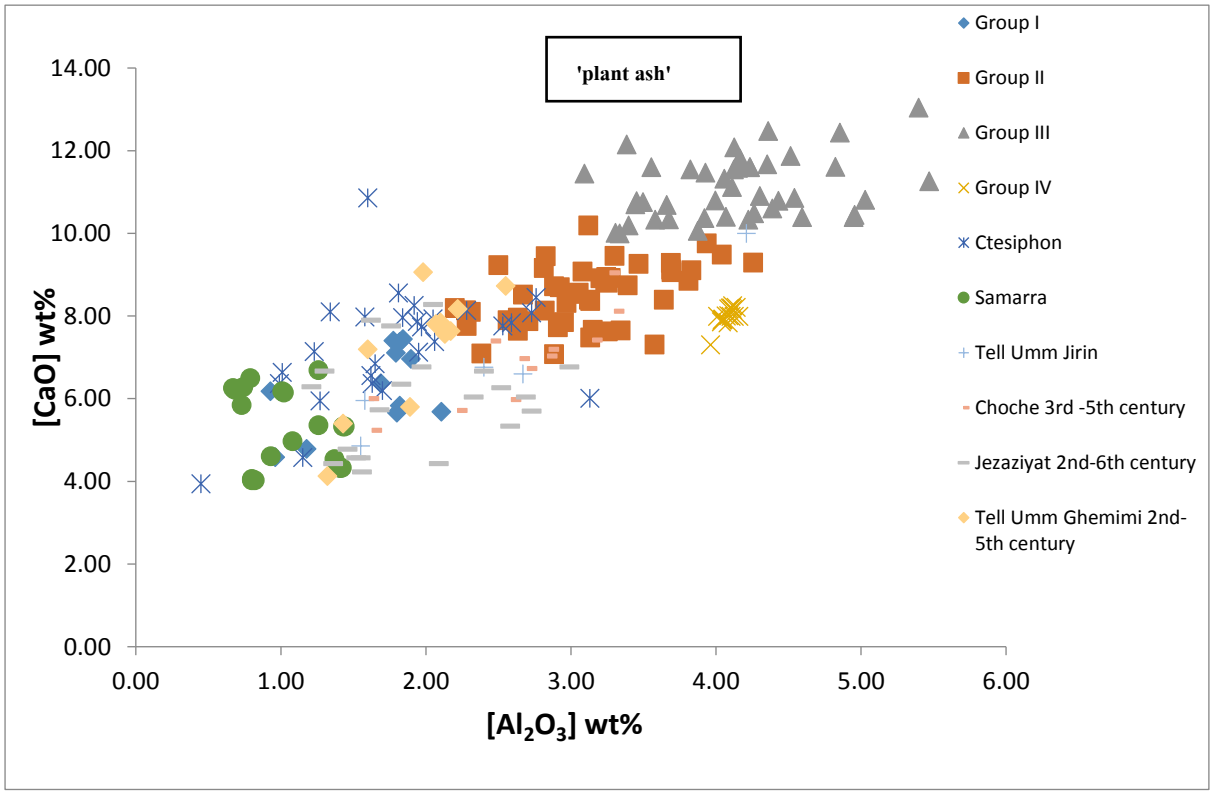


Figure 6.3.1.1: *Plot of alumina versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and six Iraqi archaeological sites.*

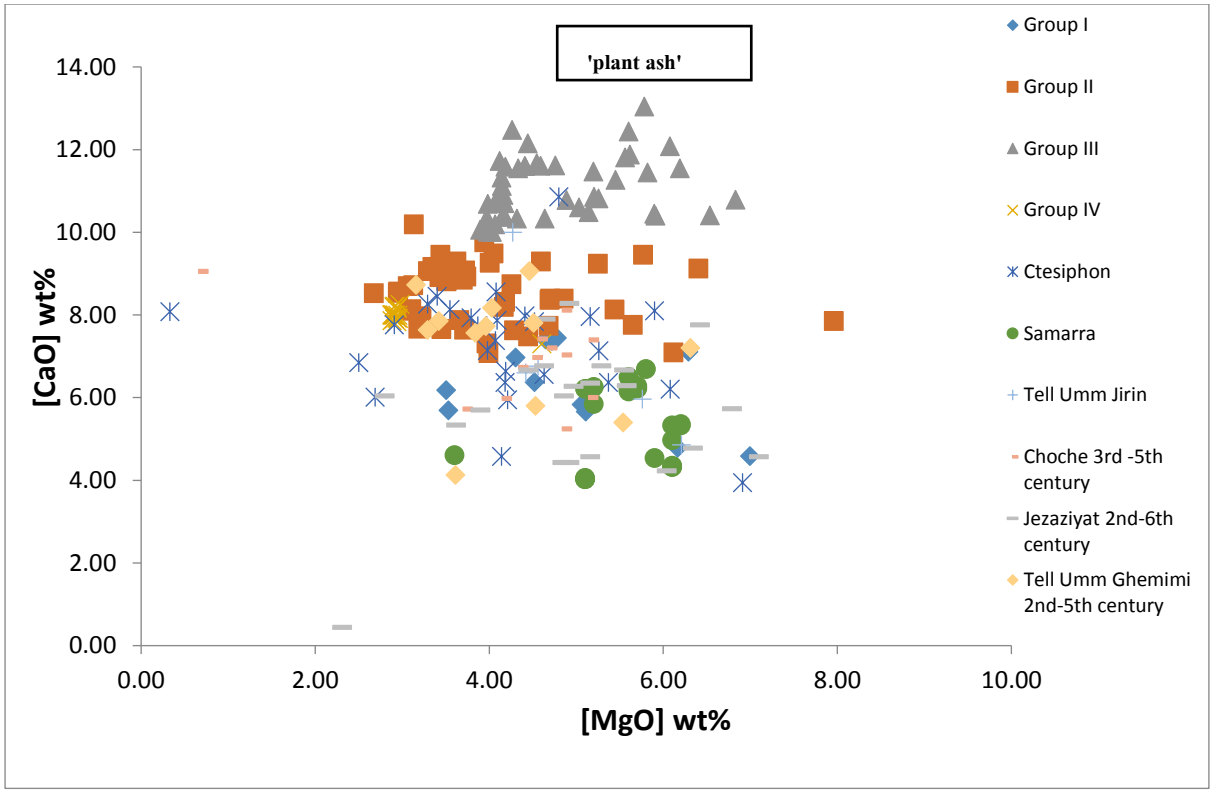


Figure 6.3.1.2: *Plot of magnesium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and six Iraqi archaeological sites.*

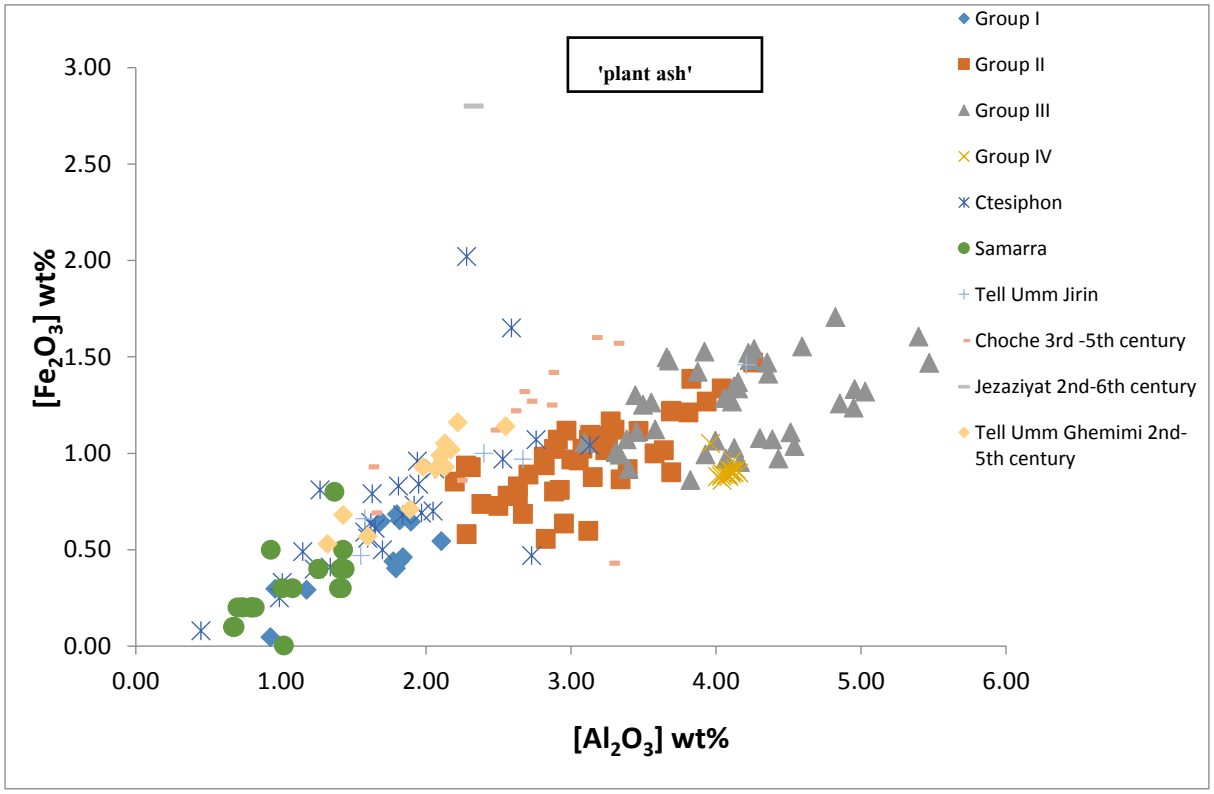


Figure 6.3.1.3: *Plot of aluminium versus iron for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and six Iraqi archaeological sites.*

Table 6.8. **Group I** glasses resemble glasses from Iraq/Iran.

Sample	Type	Group	Type/form	Resemblance
GL 1364	Plant-ash	Group I	Open-stepped rim, beaker/bowl	Ctesiphon
GL 1329	Plant-ash	Group I	Open-stepped rim, beaker/bowl	Ctesiphon
GL 1356	Plant-ash	Group I	Open-stepped rim, beaker/bowl	Ctesiphon
GL 879	Plant-ash	Group I	Closed ribbed neck, bottle or small container	Ctesiphon
GL 923	Plant-ash	Group I	Closed ribbed neck, bottle or small container	Ctesiphon
GL 692	Plant-ash	Group I	Closed ribbed neck, bottle or small container	Ctesiphon
GL 1264	Plant-ash	Group I	Closed ribbed neck, bottle or small container	Ctesiphon
GL 1003	Plant-ash	Group I	Open- plain fine, beaker/bowl	Ctesiphon
GL 15	Plant-ash	Group I	Closed & semi-open flaring straight, bottle	Ctesiphon
GL 1234	Plant-ash	Group I	Closed & semi-open flaring straight, bottle	Nishapur
GL 1848	Plant-ash	Group I	Closed-plain vertical neck, jug	Sāmarrā
GL 85	Plant-ash	Group I	Open-inwards folded rim, beaker/bowl	Sāmarrā

Figure 6.3.1.1 shows that in seven glass samples of ***Group I*** the aluminium content is high, ranging from 1.82 to 2.11% and the lime content is also high, ranging from 6.18 to 7.41%. The seven glass samples are distinguishable from the others of the same group because they have the highest concentration of alumina and lime. Alumina and lime can be very useful for classifying early Islamic glasses. In previous trace elements studies (Henderson *et al.*,2016:138), similar ranges of alumina and lime were suggested for glasses came from Ctesiphon. Under such favourable circumstances, the seven glass samples with those ratios resemble glasses from Ctesiphon. Two of the samples (GL85, GL1848) from ***Group I*** contain 0.96 to 1.18% alumina and 4.58 to 4.79% lime. There is an observable similarity between ***Group I*** glasses and glasses from Sāmarrā. It should be noted that a closed and semi-open flared straight vessel (GL1234) with 0.93% alumina and 6.18% lime concentration that resembles the colourless cut facetted vessels that were produced at Nishapur, which had low aluminium (0.93%), low magnesium (3.30%) and high silica (72.84%) concentrations. ***Group III*** and most of ***Group II*** are distinguishable from the rest of the glass from the other six Iraqi sites. Three Iranian sites were also chosen for comparison. ***Figures 6.3.1.4 - 6.3.1.6*** show the comparison.

Figure 6.3.1.2 a bi-plot of magnesium versus lime shows the distinctive CaO levels for ***Group I*** and most of ***Group II*** but the other Iraqi glasses plotted show a very similar range of MgO as in ***Groups I*** and ***II***. Two glass samples from ***Group I*** with magnesium range 6.17-7.00% and alumina range 4.58-4.79% appear correlated in their magnesium and lime content with vessels that were produced at Sāmarrā. The majority of the ***Group I*** samples have elevated lime, ranging from 6.18 to 7.41% and lower magnesium, ranging from 3.50 to 4.72%. The above ranges match with samples come from Ctesiphon. It will be seen in the next figure, ***Figure 6.3.1.3***, that the majority of ***Group I*** samples differs from Sāmarrā glasses having elevated iron composition. The iron ranges are between 0.40 to 0.68% while the Sāmarrā glasses iron ranges are lower 0.29 to 0.50%. Two of the samples (GL85, GL1848) from ***Group I*** contain 0.29 to 0.30% iron content that matches with those from Sāmarrā. It can be seen in ***Figure 6.3.1.3*** that the overall range of the iron ranges of the majority of ***Group I*** samples matches with iron ranges of the Ctesiphon glasses. Again it can be seen that ***Group I*** and most of ***Group II*** have higher aluminium levels.

Figures 6.3.1.1-6.3.1.3 show that one sample (GL1234) based on its position on the graphs and having the lower alumina 0.93% and magnesium 3.50% concentration, the lowest iron content 0.05% and the higher lime 6.18% concentration it surely does not belong to Ctesiphon and Sāmarrā glasses and therefore probably came from a different source. It is worth emphasizing that GL1234 elemental concentration is a very close match with glasses from Nishapur. One reasonable explanation is that made in Nishapur (Henderson *et al.*,2016:142). For that matter, to add any useful information for its classification all the Kadhima, Shiqaya and Mughaira samples will be compared with samples from three Iranian sites. *Figures 6.3.1.4-6.3.1.6* shows the comparison. Sample GL1234 contains 6.18% lime and 0.93% alumina and plot on the right of the graph in *Figure 6.3.1.4,* next to Nishapur colourless glasses. It seems likely to us that there is some sort of connection between GL1234 sample and to the colourless cut facetted vessels that previous trace element analysis has proved that were produced at Nishapur.

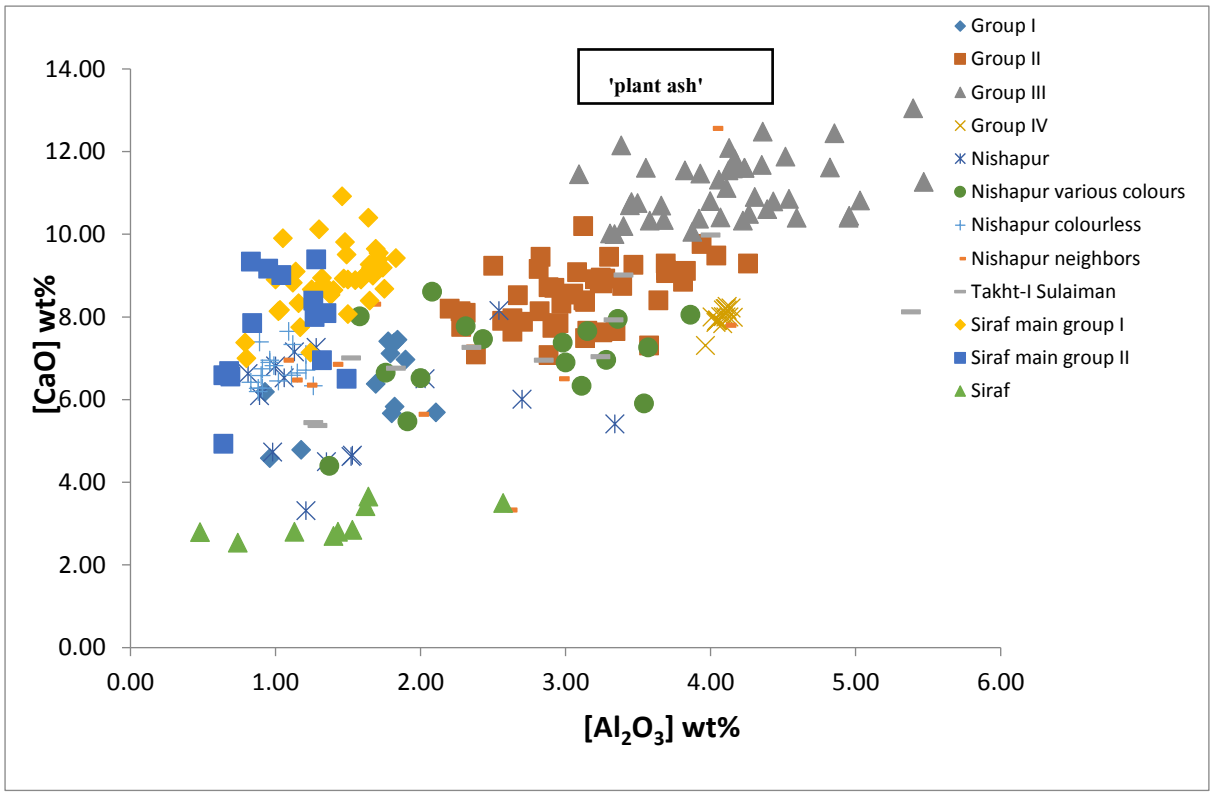


Figure 6.3.1.4: Plot of aluminium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and three Iranian archaeological sites.

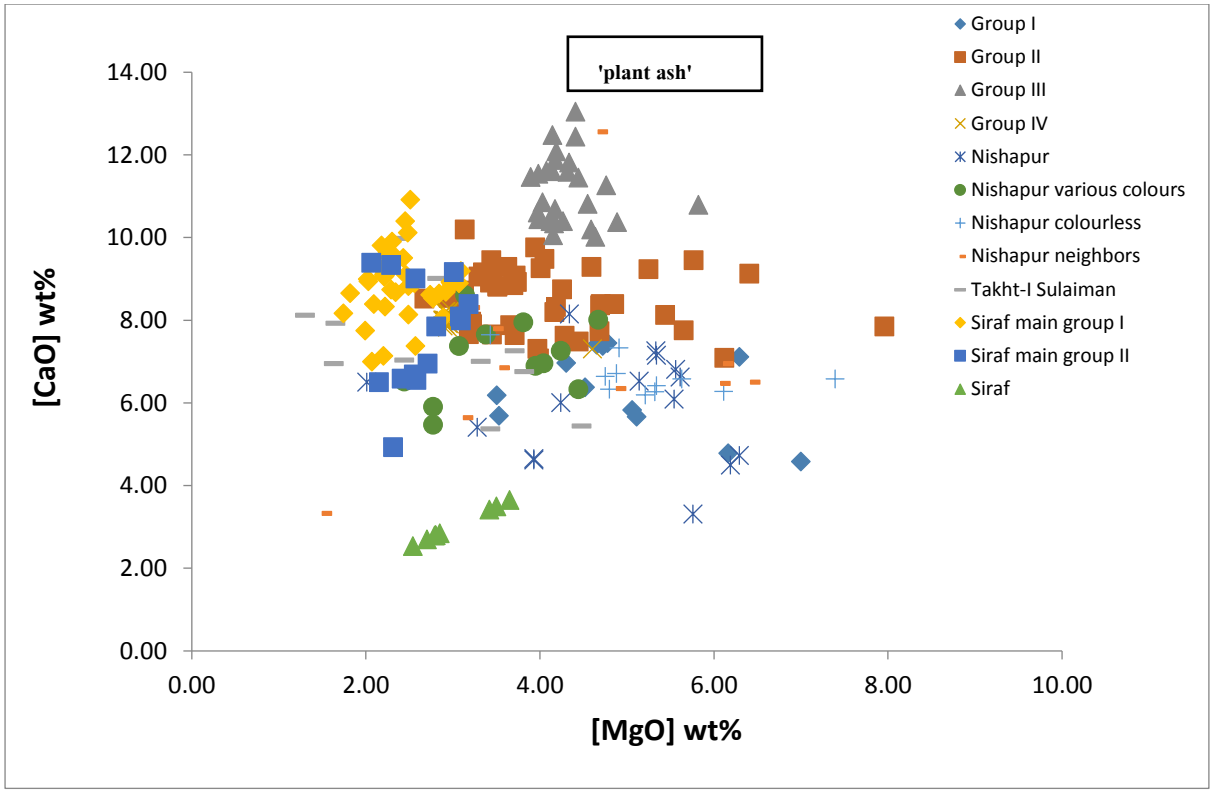


Figure 6.3.1.5: *Plot of magnesium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and three Iranian archaeological sites.*

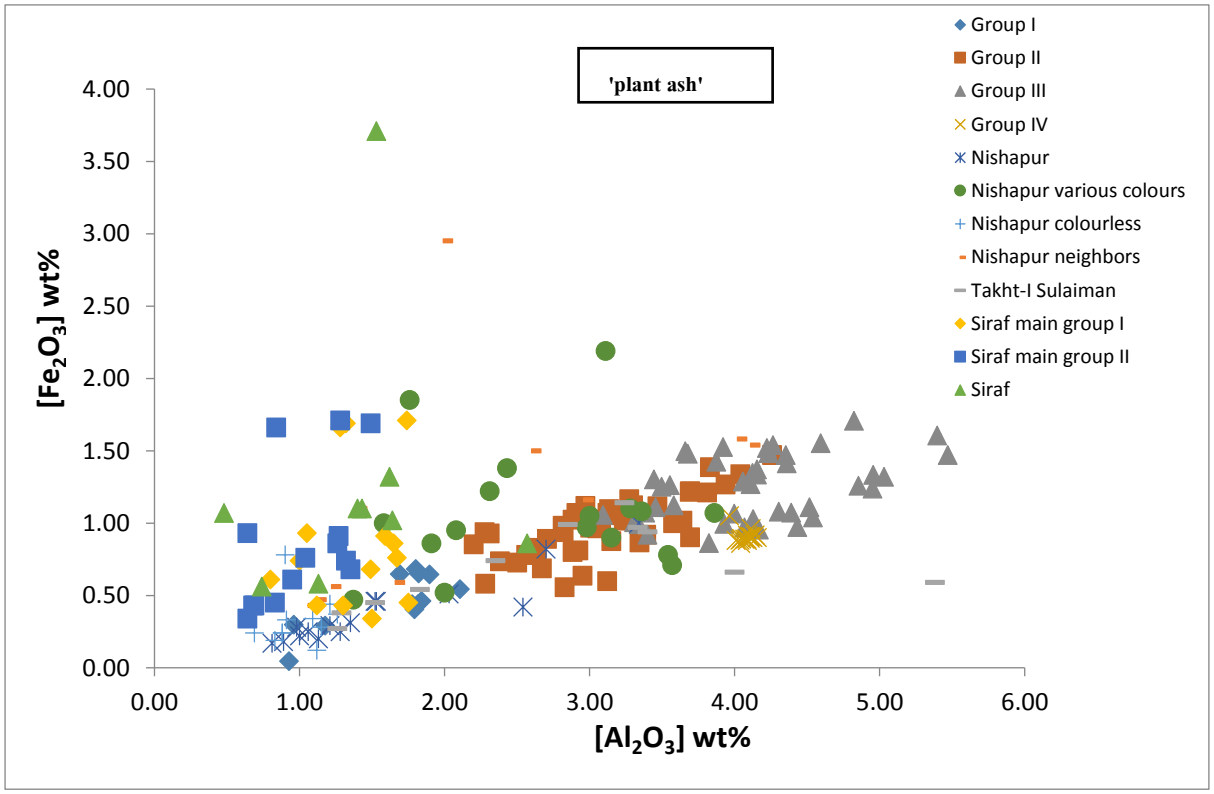


Figure 6.3.1.6: *Plot of aluminium versus iron for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and three Iranian archaeological sites.*

It should be noted that the bi-plot in ***Figure 6.3.1.4*** indicates that GL1234 sample is distinctly different not only from Nishapur various colours glasses but also from the Takht-I Sulaiman and Siraf glasses. In ***Figure 6.3.1.4*** it can be seen that GL1234 sample falls somewhat below Siraf main group I and Siraf main group II that having higher alumina >1% and lime >6% ranges. It is worth pointing out that in ***Figure 6.3.1.5*** GL1234 sample having magnesium rates 3.50% which is slightly lower than colourless glass from Nishapur having magnesium content more than 4%. However, the comparison points out the problems that can arise when comparing only one or two elements. It is certainly helpful ***Figure 6.3.1.5*** to see if the similarity with Nishapur colourless cut facetted vessels can be proved. ***Figure 6.3.1.6*** indicates that GL1234 sample having 0.05% iron resemble Nishapur colourless cut facetted vessels and is distinctly different from Siraf main group I, Siraf main group and Takht-I Sulaiman glasses having more than 0.40 iron content. In summary, the results obtained by the above comparison show a clear similarity between GL1234 sample and colourless cut facetted vessels produced at Nishapur.

6.3.2 Group II - high-magnesia or plant-ash glass

Group II in this study comprises the majority of the vessels (n=48) (**Table 6.9a** and **Table 6.9b**).Two distinct subtypes of glass were identified among the ***Group II*** samples. It is noteworthy that glass from ***Group II*** resembles the chemical composition of al-Raqqa ***Type 2*** glass from Syria, a fact that supports the assumption of a Syrian centre of diffusion (Henderson,1999:438; Henderson *et al.*,2004:452;Henderson *et al.*,2016:138).***Group II*** has the compositional characteristics of high magnesia glass from Tell Zujaj, differing from other early Islamic glasses because of the high magnesia content. All of the ***Group II*** samples have relatively high aluminium oxide levels, between 2.20% and 3.95%, lower magnesium, slightly lower silica, and higher iron and manganese oxides than other Islamic glasses (Henderson,1999:436;Henderson,2004:444).

The Kuwaiti samples are compared with two archaeological sites from al-Raqqa and one from Damascus dated back to the early Islamic times. The comparison is shown in ***Figures 6.3.2.1-6.3.2.3***. The figures clearly show the close compositional relationship between ***Group II*** glass and the Syrian Tell Zujaj glass. Of note is the fact that ***Group II*** glass is clearly distinguishable and significantly differs from the 11th century AD Tell Fukhkhar and 12th century AD Damascus assemblages, but ***Group II*** glass positively correlates with Tell Zujaj (Henderson, 2004:449-450, Henderson *et al.*,2016:136). The reason for this positive correlation is that ***Type II*** was made in Tell Zujaj from the late 8th to early 9th century AD. Chemical analysis of a vitreous component of an overheated frit in Tell Zujaj, in combination with the archaeological remains, provided evidence for glass production at Tell Zujaj (Henderson,1999; Henderson *et al.*,2004). Hence, the suggestion is that Tell Zujaj might be the possible place of production of ***Group II*** glass.

A glance through ***Figures 6.3.2.1- 6.3.2.3*** shows compositional spread for ***Group II*** somewhat bigger than the ***Group I*** samples. It is unclear whether the large compositional spread represents variation in the raw materials (many different consignments of raw glass or cullet) or indicates the presence of materials from more than one place. Glass of ***Type II*** has also been identified in Unguja Ukuu, Zanzibar, Nishapur and Ctesiphon. A minor point must be made here. All the samples containing less than 8% soda were removed. Lime typically occurs in plant ash glasses at levels of 8%-10% as it reduces their solubility in water (Freestone,2006:12). Plant ash glass with lime at levels under 8% is not environmentally stable and has weathered (Freestone,2006:12). ***Group II*** comprises thirteen open-triangular beaked rims, five open

Table 6.9.a Group II closed and semi-open types glasses resemble glasses from al-Raqqa.

Sample	Type	Group	Type/form	Resemblance
GL 2041	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 736	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 1060	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 1132	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 1213	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 778	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 998	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 838	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 1062	Plant-ash	Group II	Closed & semi-open flaring straight	al-Raqqa, Type 2
GL 1072	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 1674	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 1114	Plant-ash	Group II	Closed &semi-open flaring straight	al-Raqqa, Type 2
GL 1995	Plant-ash	Group II	Closed & semi-open flaring-rolled in	al-Raqqa, Type 2
GL 155	Plant-ash	Group II	Closed & semi-open flaring-rolled in	al-Raqqa, Type 2
GL1574	Plant-ash	Group II	Closed & semi-open flaring-rolled in	al-Raqqa, Type 2
GL 72	Plant-ash	Group II	Closed & semi-open flaring-rolled in	al-Raqqa, Type 2
GL 253	Plant-ash	Group II	Closed & semi-open flaring-rolled in	al-Raqqa, Type 2
GL 1381	Plant-ash	Group II	Closed & semi-open and flattened rim	al-Raqqa, Type 2
GL 1761	Plant-ash	Group II	Closed & semi-open and flattened rim	al-Raqqa, Type 2
GL 81	Plant-ash	Group II	Closed & semi-open and flattened rim	al-Raqqa, Type 2
GL 1323	Plant-ash	Group II	Closed & semi-open and flattened rim	al-Raqqa, Type 2
GL 1308	Plant-ash	Group II	Closed-ribbed neck	al-Raqqa, Type 2
GL 1269	Plant-ash	Group II	Closed-ribbed neck	al-Raqqa, Type 2

Table 6.9.b Group II open types glasses resemble glasses from al-Raqqa.

Sample	Type	Group	Type/form	Resemblance
GL 1680	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 80	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 1588	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 236	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 1152	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 1677	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 218	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 1856	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 83	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 1856	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL1547	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 1603	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 83	Plant-ash	Group II	Open-triangular beaked rim	al-Raqqa, Type 2
GL 1077	Plant-ash	Group II	Open-inwards folded rim	al-Raqqa, Type 2
GL 1947	Plant-ash	Group II	Open-inwards folded rim	al-Raqqa, Type 2
GL 151	Plant-ash	Group II	Open-inwards folded rim	al-Raqqa, Type 2
GL 61	Plant-ash	Group II	Open-inwards folded rim	al-Raqqa, Type 2
GL 1577	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 1335	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 1371	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 898	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 771	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
Sample	**Type**	**Group**	**Type/form**	**Resemblance**

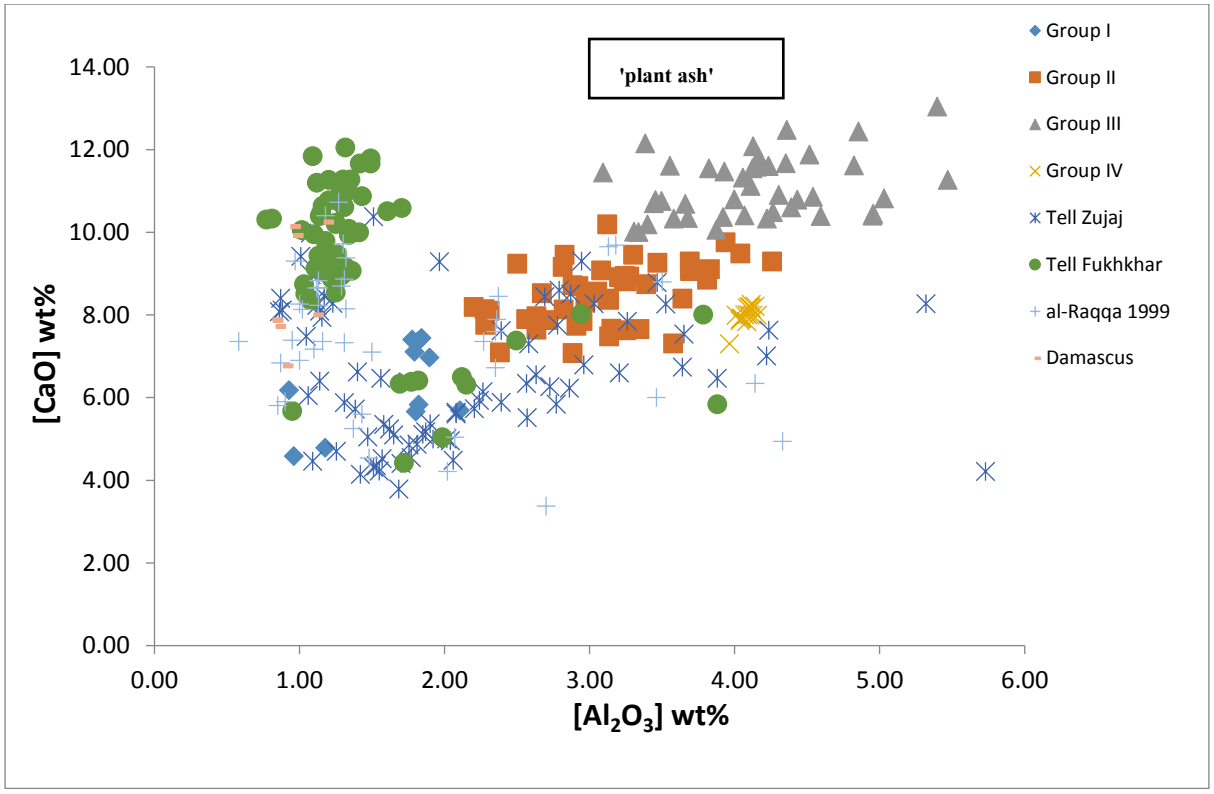


Figure 6.3.2.1: *Plot of aluminium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and three Syrian archaeological sites.*

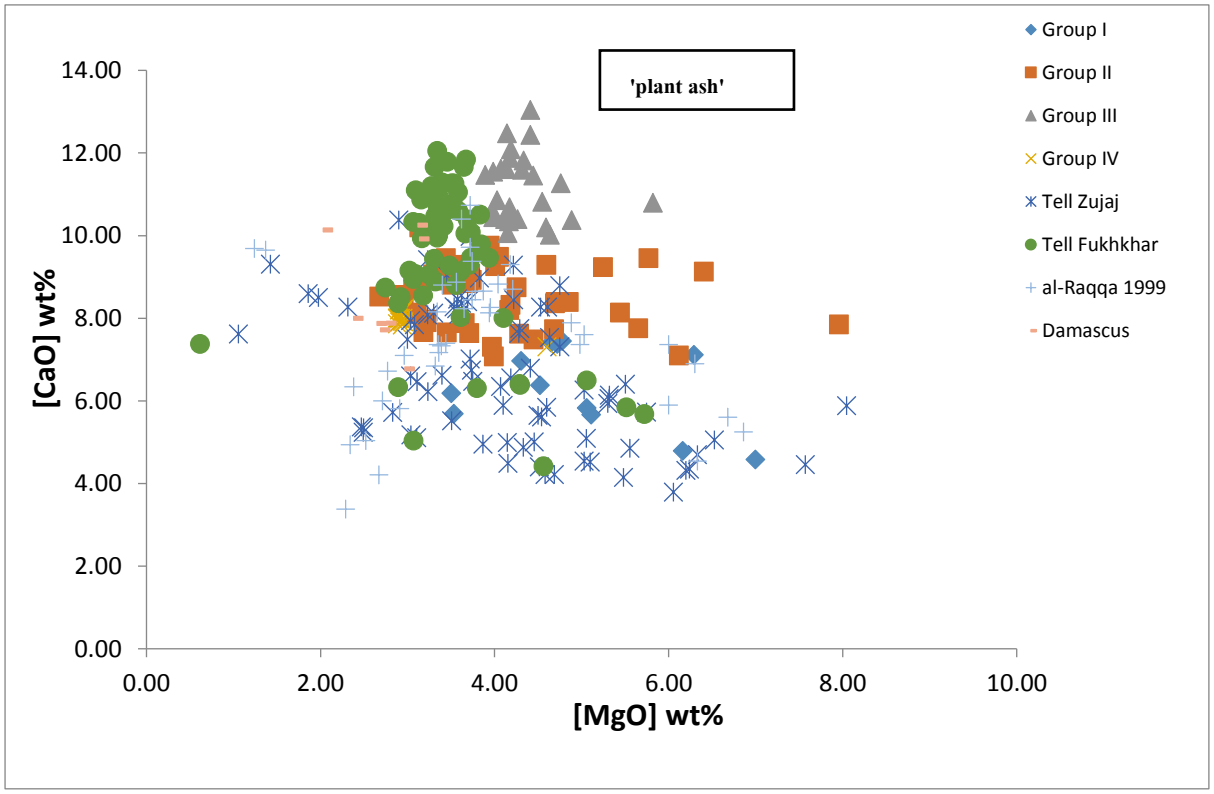


Figure 6.3.2.2: *Plot of magnesium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and three Syrian archaeological sites.*

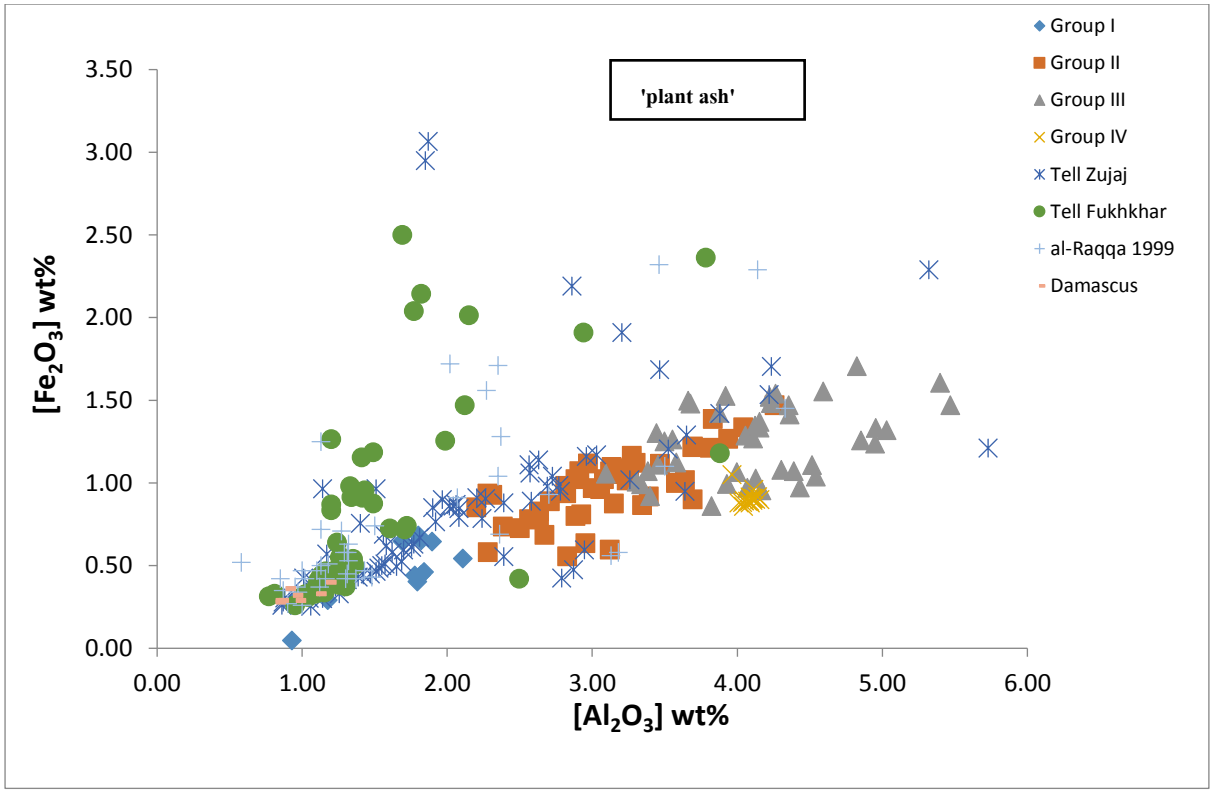


Figure 6.3.2.3: *Plot of aluminium versus iron for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and three Syrian archaeological sites.*

stepped rims, four inwardly-opening folded rims, three open-plain fine rims and one open-flared sided rim. Of the closed types, there are thirteen closed and semi-open flaring straight, five closed and semi-open flaring-rolled in, four closed and semi-open flattened rims and two closed ribbed necks.

It is worth pointing out that in ***Figure 6.3.2.1*** appears to be a general trend in which the samples from Tell Fukhkhar and Damascus form a rather tight cluster at the upper left of the graph, while ***Group II*** glasses spread in the middle toward the right and plot close to Tell Zujaj samples. The ***Group II*** glasses have high alumina content, ranging from 2.28 to 4.26%, and high lime content, ranging from 7.66 to 10.20%, similar to Tell Zujaj samples. In the most straightforward instances, ***Group II*** glasses with the specific alumina and lime content are likely to have come from the Tell Zujaj. It must be pointed out that Tell Zujaj from the late 8th to early 9th century AD provided evidence for glass production (Henderson,1999; Henderson *et al.*,2004). Under favourable circumstances with evidence of glass production, the comparison in ***Figure 6.3.2.1*** can be utilized for confirming, either directly or indirectly, Tell Zujaj as the location of ***Group II*** glass manufacture.

Figure 6.3.2.2 shows that magnesium contents cannot be very helpful for matching ***Group II*** glasses with Tell Zujaj and Tell Fukhkhar. The data plotted in *Figure 6.3.2.2* indicates that ***Group II*** glasses are slightly different from Damascus glasses that had the lowest magnesium concentration >3%. In addition, it can be seen that ***Group II*** glasses plot between Tell Zujaj and Tell Fukhkhar glasses though slightly closest to Tell Zujaj with magnesium content higher than 4% which has been identified for Tell Fukhkhar glasses. Because *Figure 6.3.2.2* indicates no clear matches for ***Group II*** glasses, it was decided to include a third graph *Figure 6.3.2.3* The overall range of iron concentration of the ***Group II*** glasses is between 0.60 to 1.39%, which is approximately closer to Tell Zujaj glasses. In contrast, the majority of Tell Fukhkhar glasses have iron concentration less than 0.50% with the highest iron content 1,00%. The bi-plot in *Figure 6.3.2.3.* shows that Tell Fukhkhar glasses form a rather tight cluster with low aluminium and iron oxide levels while Tell Zujaj and ***Group II*** glasses plot at the upper right and therefore they came from a similar source.

6.3.3 Group III high-magnesia or plant-ash glass

We now come to the group that is designated as ***Group III***, comprising 45 vessels. ***Group III*** comprises fourteen inwardly-opening folded rims, four open stepped rims, six open rolled-in rims and one open plain fine (**Table 6.10a** and **Table 6.10b**). From the closed types, there were eleven closed and semi-open flaring straight, ten closed and semi-open folded and flattened rims, one closed and semi-open flaring-rolled in and one closed ribbed neck. Two distinct subtypes of glass were identified among the ***Group III*** samples. The first subtype, ***Group IIIa***, comprises 16 samples, which contain low levels of Na_2O (between 5.78% - 9.48%), higher silica (between 62.91% - 68.43%) and higher MgO (between 4.03% - 4.89%), while the second subtype, ***Group IIIb***, which contains increased levels of soda (14.86% - 16.99%), lower silica (between 58.59% - 60.13%) and lower MgO (between 3.31% - 4.26%), is represented by 29 samples. In terms of its chemical composition, ***Group III*** is characterised by distinctly different levels of soda and silica and by exceptionally high aluminium and lime concentrations. This group vary considerably from known early Islamic glasses. Glass showing these characteristic elemental features are in stark contrast to all published glasses. Therefore, it is not discussed elsewhere. ***Group III*** glasses were normally naturally-coloured light green-blue (in a large range of shades and hues), and naturally-coloured bright 'emerald' green or olive-green glass and were by far one of the most dominant groups. It is noteworthy that this group is considered to be the most important because it demonstrates a rare new plant ash compositional type. Here we must search for evidence of a new glass production centre, perhaps in Iraq. Part of the challenge was to search for evidence in Egypt, Levant and Iraq. ***Figures 6.3.3.1-6.3.3.3*** show the comparison between the Kuwaiti samples and samples from the above places.

After a careful survey of a number of chemically analysed samples inside and outside the Islamic world and comparisons with samples from Iraq (Sāmarrā, Ctesiphon, Choche, Tell Umm Jirin, Tell Umm Ghemimi, Jezaziyat) Iran (Sīrāf, Nishapur, Takht-i Sulaiman) and Syria (al-Raqqa, Damascus) two matching samples have been found. These two are sample 1260, excavated in a small tell containing large quantities of molten glass refuse in Tel Umm Jirin, Iraq, and sample 5341, excavated in Hamadan, Iran, close to the ***Group III*** samples. The evidence from the chemical analysis shows that sometime later in the 7th century AD, the specific plant ash

Table 6.10a Group III closed and semi-open types glasses resemble glasses from unknown source.

Sample	Type	Group	Type/form	Resemblance
GL 725	Plant-ash	Group IIIa	Closed &semi-open folded and flattened rim	unknown source
GL 1652	Plant-ash	Group IIIa	Closed &semi-open folded and flattened rim	unknown source
GL 2068	Plant-ash	Group IIIa	Closed &semi-open folded and flattened rim	unknown source
GL 1944	Plant-ash	Group IIIb	Closed &semi-open folded and flattened rim	unknown source
GL 1944	Plant-ash	Group IIIb	Closed &semi-open folded and flattened rim	unknown source
GL 1223	Plant-ash	Group IIIb	Closed &semi-open folded and flattened rim	unknown source
GL 719	Plant-ash	Group IIIb	Closed &semi-open folded and flattened rim	unknown source
GL 361	Plant-ash	Group IIIb	Closed &semi-open folded and flattened rim	unknown source
GL 718	Plant-ash	Group IIIb	Closed &semi-open folded and flattened rim	unknown source
GL 1530	Plant-ash	Group IIIb	Closed &semi-open folded and flattened rim	unknown source
GL 1039	Plant-ash	Group IIIa	Closed &semi-open flaring straight	unknown source
GL 269	Plant-ash	Group IIIa	Closed &semi-open flaring straight	unknown source
GL 559	Plant-ash	Group IIIa	Closed &semi-open flaring straight	unknown source
GL 779	Plant-ash	Group IIIa	Closed &semi-open flaring straight	unknown source
GL 2110	Plant-ash	Group IIIb	Closed & semi-open flaring straight	unknown source
GL 2041	Plant-ash	Group IIIb	Closed & semi-open flaring straight	unknown source
GL 2045	Plant-ash	Group IIIb	Closed & semi-open flaring straight	unknown source
GL 651	Plant-ash	Group IIIb	Closed & semi-open flaring straight	unknown source
GL 1004	Plant-ash	Group IIIb	Closed & semi-open flaring straight	unknown source
GL 82	Plant-ash	Group IIIb	Closed & semi-open flaring straight	unknown source
GL 773	Plant-ash	Group IIIb	Closed & semi-open flaring straight	unknown source
GL 396	Plant-ash	Group IIIb	Closed & semi-open flaring-rolled in	unknown source
GL 1675	Plant-ash	Group IIIb	Closed ribbed rim	unknown source

Table 6.10.b Group III open types glasses resemble glasses from unknown source.

Sample	Type	Group	Type/form	Resemblance
GL 1118	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 1786	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 1808	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 1662	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 150	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 534	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 639	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 534	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 1786	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 1118	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 1808	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 1662	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 150	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 1561	Plant-ash	Group IIIa	Open inwards-folded rim	unknown source
GL 258	Plant-ash	Group IIIa	Open-stepped rim	unknown source
GL 258	Plant-ash	Group IIIa	Open-stepped rim	unknown source
GL 84	Plant-ash	Group IIIb	Open-stepped rim	unknown source
GL 1351	Plant-ash	Group IIIb	Open-stepped rim	unknown source
GL 1230	Plant-ash	Group IIIa	Open rolled-in rim	unknown source
GL 861	Plant-ash	Group IIIa	Open rolled-in rim	unknown source
GL 1230	Plant-ash	Group IIIa	Open rolled-in rim	unknown source
GL 149	Plant-ash	Group IIIa	Open rolled-in rim	unknown source
GL 861	Plant-ash	Group IIIb	Open rolled-in rim	unknown source

Sample	Type	Group	Type/form	Resemblance
GL 1230	Plant-ash	Group IIIb	Open rolled-in rim	unknown source
GL 233	Plant-ash	Group IIIa	Open-triangular beaked rim	unknown source
GL 1363	Plant-ash	Group IIIa	Open-plain rounded	unknown source
GL 640	Plant-ash	Group IIIa	Open plain-fine	unknown source

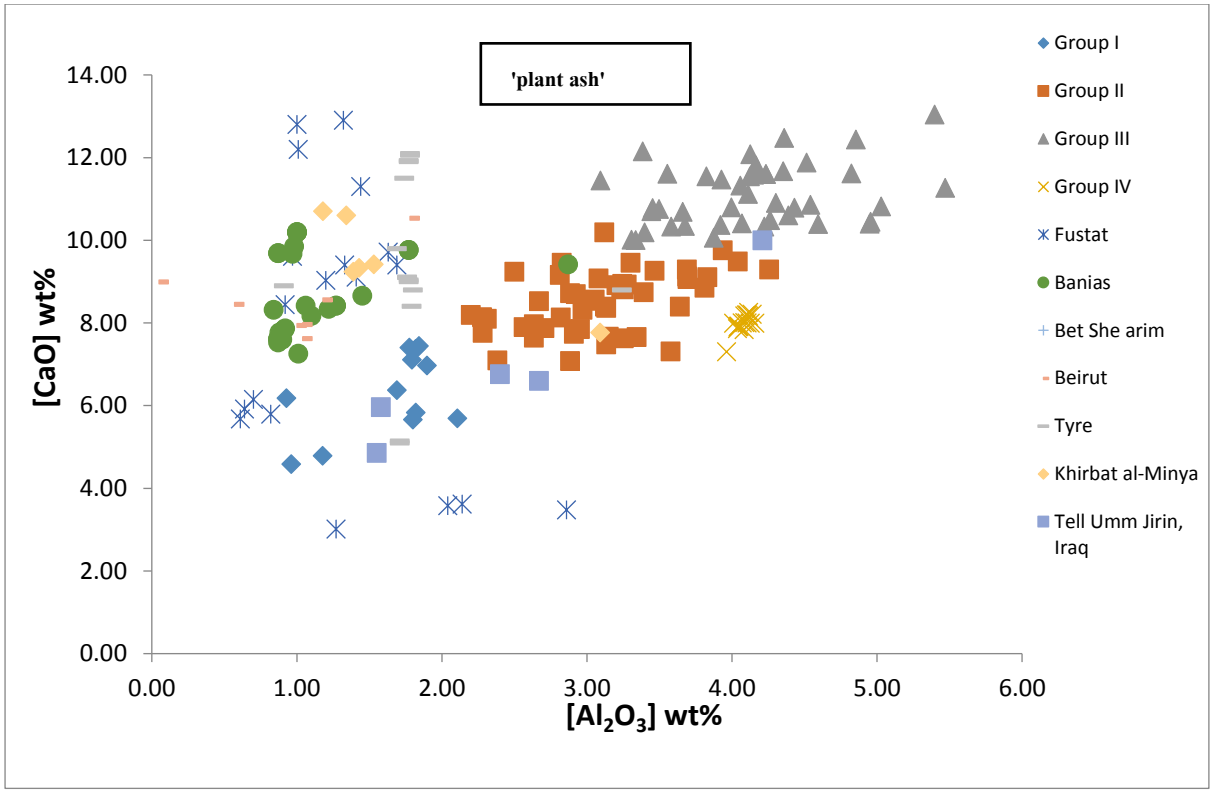


Figure 6.3.3.1: *Plot of aluminium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and archaeological sites from Egypt, Levant and Iraq.*

compositional group become widespread in Kadhima, Mughaira, Shiqaya in the Persian Gulf and in Unguja Ukuu on the East African coast. It is worth pointing out that eleven samples from Unguja Ukuu resemble the chemical composition of ***Group III*** glass and will be described in more detail in subchapter 6.6.

In ***Figure 6.3.3.1*** ***Group III*** glasses are plotted as triangles on the right part of the graph close to sample 1260, excavated in a small tell containing large quantities of molten glass refuse in Tel Umm Jirin, Iraq. It can be seen after an examination of ***Figure 6.3.3.1*** that ***Group III*** glasses are distinctly different having the higher alumina contents of between 3.34 to 5.47% compared to glasses from Fusṭāṭ , Banias, Bet Shearim, Beirut and Khirbat al-Minya glasses having >2% alumina. Based on its position on the left on the graph the majority of the Egyptian and Levantine glasses differs from ***Group III*** samples having lower than 10% lime. In ***Figure 6.3.3.1*** appears to be a general trend in which ***Group III*** glasses do not form a tight cluster at the upper right but form a large compositional spread in somewhat similar to the ***Group II*** samples. Whether ***Group III*** glasses came from the same region but were made from many different raw materials (many different consignments of raw glass or cullet) or from materials coming from more than one place is not known at this time.

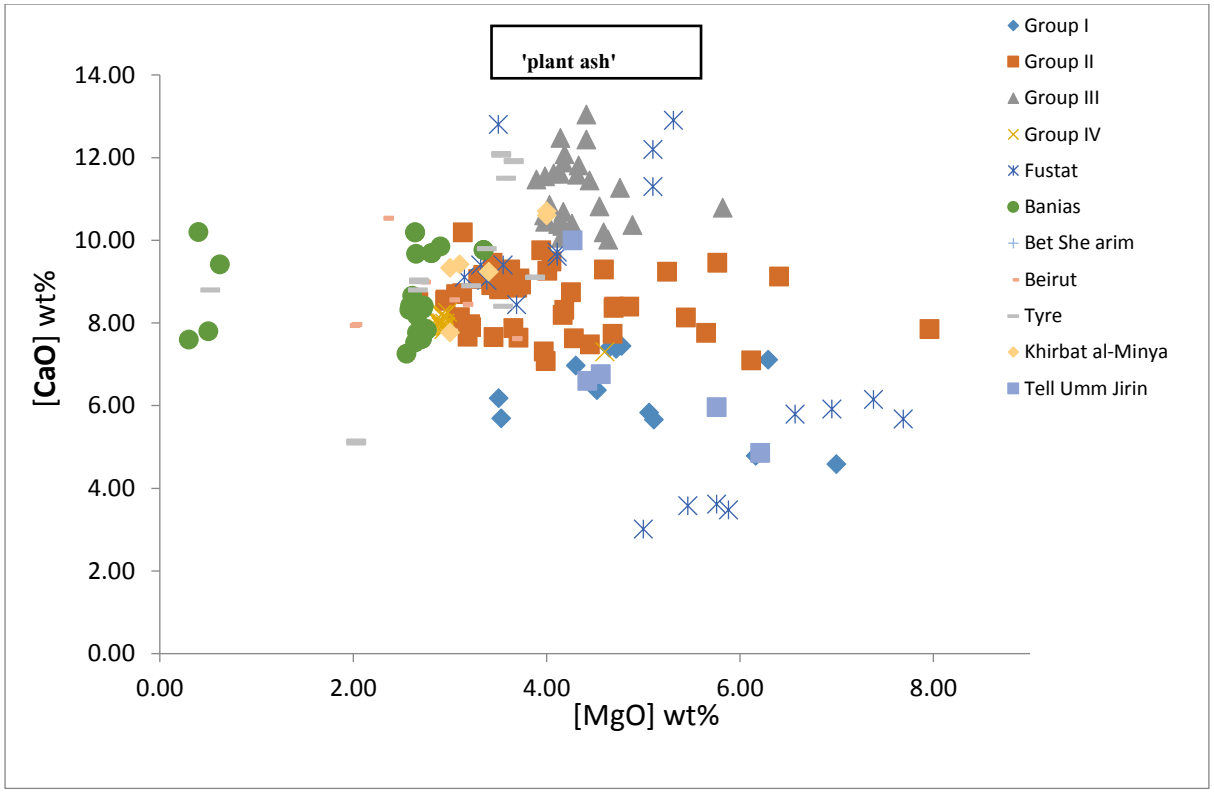


Figure 6.3.3.2: *Plot of magnesium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and archaeological sites from Egypt, Levant and Iraq.*

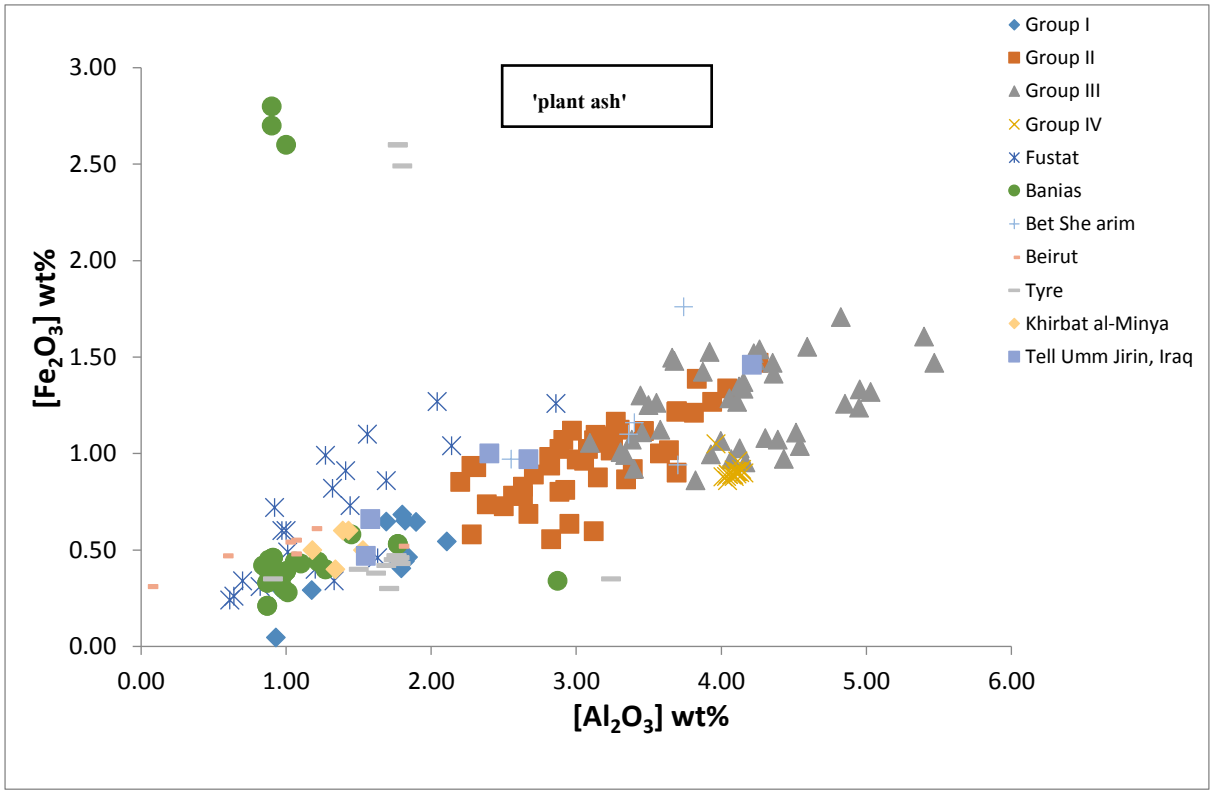


Figure 6.3.3.3: *Plot of aluminium versus iron for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and archaeological sites from Egypt, Levant and Iraq.*

Differences between ***Group III*** glasses and Egyptian and Levantine glasses were observed in ***Figure 6.3.3.2***. ***Figure 6.3.3.2*** shows magnesium and lime contents in a graph. Apart from one sample the range of magnesium for ***Group III*** glasses is between 3.89 to 6.19% lower than the majority of Fusṭāṭ glasses more than 5.50% and higher than Khirbat al-Minya, Beirut and Bet Shearim glasses more than 4%. However, ***Group III*** glasses plot lower down-close to some Tyre samples though slightly different with lower magnesium content less than 3.50%. It is worth pointing out that ***Group III*** glasses are distinctly different in magnesium content from Banias glasses falling below on the left at the graph having less than 3.00% magnesium content. The iron values in ***Group III*** glasses vary widely from the Levantine glasses and less from the Egyptian glasses, covering a range of 0.86 to 1.71%. The bi-plot in ***Figure 6.3.3.2*** indicates that Fusṭāṭ iron levels is high between 0,20 to 1,00% and though similar to ***Group II*** glasses having lower alumina levels than ***Group III*** glasses. The Levantine glasses mainly have lower iron contents from ***Group III*** glasses, with a mean value of 0.50%. ***Figures 6.3.3.1-6.3.3.3*** and previous figures in chapter 6 have clearly shown that ***Group III*** glasses have very high alumina levels and can be distinguished from the other glasses plotted according to other oxides such as calcium. Its origin is unknown.

6.3.4 Group IV high-magnesia or plant-ash glass

The next group in this study, ***Group IV***, comprised 18 vessels (**Table 6.11**). ***Group IV*** is characterised by being compositionally very tight. The group has an alumina content of about 2.60% and lime of about 8%. The soda is typically in the range of 7-8%, and silica is typically 66%. The homogeneity of the composition of the glass, suggesting a relatively stable and fixed recipe based on silica fluxed with plant ash. By comparing alumina, lime, magnesium and iron in ***Figures 6.3.4.1-6.3.4.3***, it can be seen that all the concentrations are similar. The glasses are not distinguishable from each other in the plots but instead, they overlap, an indication that they were likely made in the same place. ***Group IV*** samples were discovered in a mud-brick structure with three rooms and a courtyard. The location was linked to a stone-lined well and cistern complex dated to the late 7th to 8th century AD, on the basis of the ceramic evidence (Blair,2016:325).

The quality of the glass was exceptional; the fragments were very thin but deteriorated. By comparing all the groups with sites in Levant, Syria and Egypt, we fail to find any matching samples. The group has similarities with glass found at Tell Zujaj, but it is clearly distinguishable. More closely related are three samples uncovered in Nishapur. A comparison of the ***Group IV*** samples with Tell Zujaj, Nishapur and neighbouring regions follows below (***Figures 6.3.4.1-6.3.4.3***). The one exception is vessel 5340 from Hamadan, a region close to Nishapur, which seems to overlap with ***Group IV*** samples.

Figure 6.3.4.1 shows that ***Group IV*** samples with alumina content between 3.96 to 4.16% lies on the right part of the graph; there are no close matches with any of the comparable glasses. It can be seen that although at the same part of the graph with Tell Zujaj glasses differs from ***Group IV*** samples having higher alumina concentration. It is worth emphasizing that a sample from Nishapur neighbours plots among ***Group IV*** samples and could have come from the same location. Two samples from Unguja Ukuu fall somewhat close to ***Group IV*** samples as seen in ***Figure 6.3.4.1*** having alumina content between 3 to 4% but nevertheless differ slightly from the glasses just discussed. In ***Figure 6.3.4.2,*** there is no observable separation between ***Group IV***

Table 6.11. Group IV glasses resemble glasses from unknown source.

Sample	Type	Group	Type/form	Resemblance
GL 1398	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1404	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1412	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1394	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1414	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1400	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1417	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1408	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1393	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1406	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1418	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1410	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1413	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1409	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1411	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1407	Plant-ash	Group IV	Glass ABC vessel	unknown source
GL 1599	Plant-ash	Group IV	Closed & semi-open flattened rim	unknown source

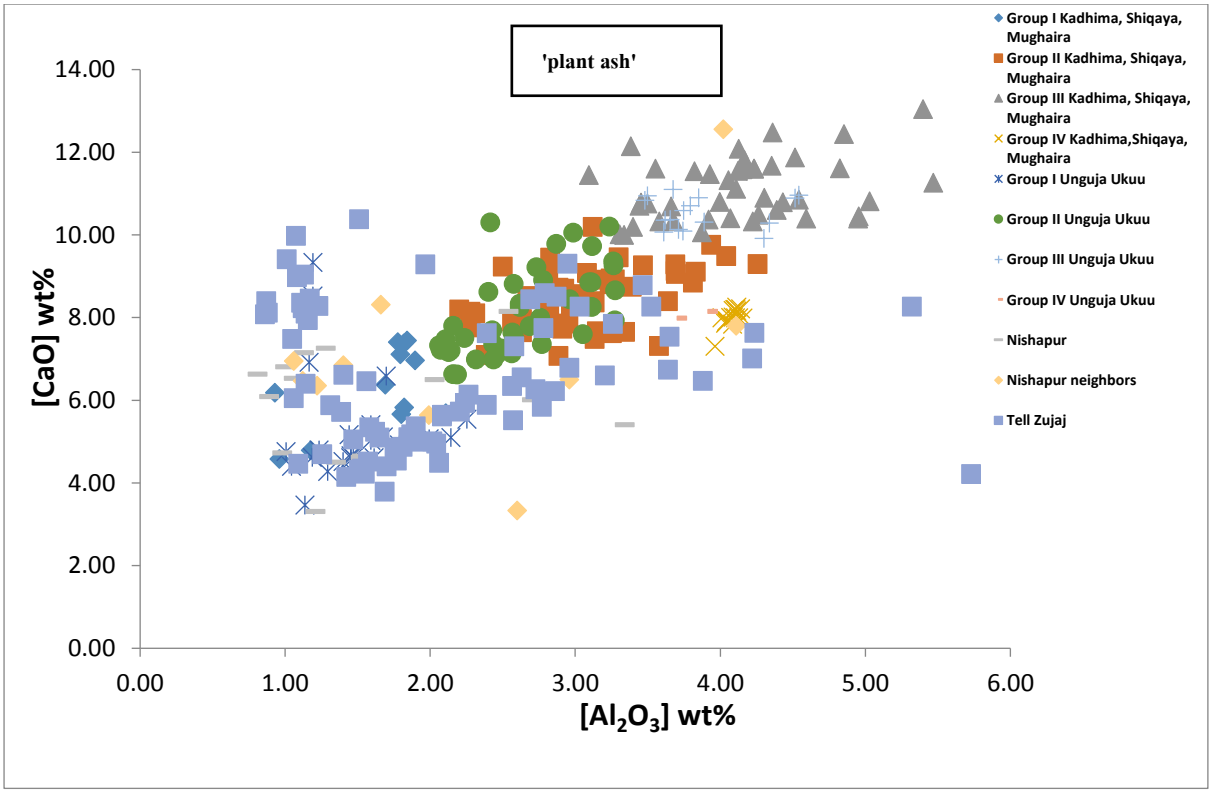


Figure 6.3.4.1: *Plot of aluminium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira and archaeological sites from Nishapur, Nishapur neighbors, Tell Zujaj and Zanzibar.*

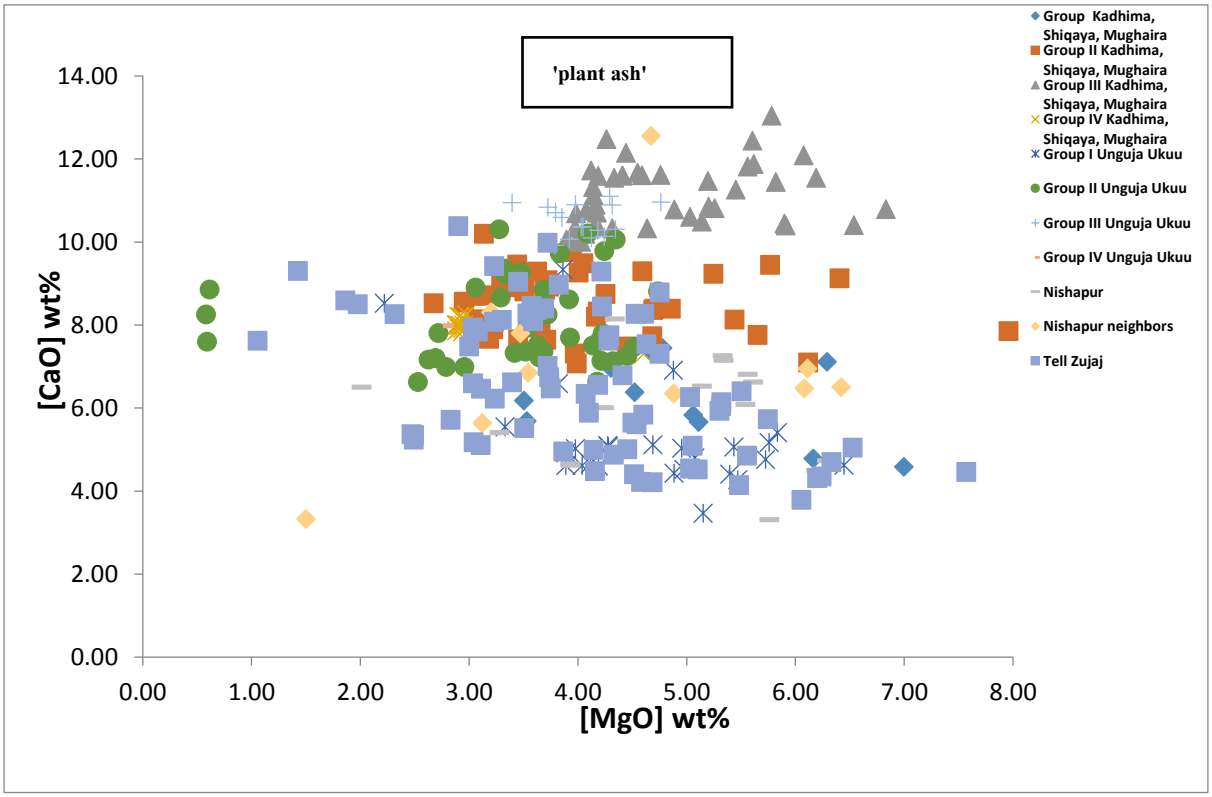


Figure 6.3.4.2: *Plot of magnesium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira and archaeological sites from Nishapur, Nishapur neighbors, Tell Zujaj and Zanzibar.*

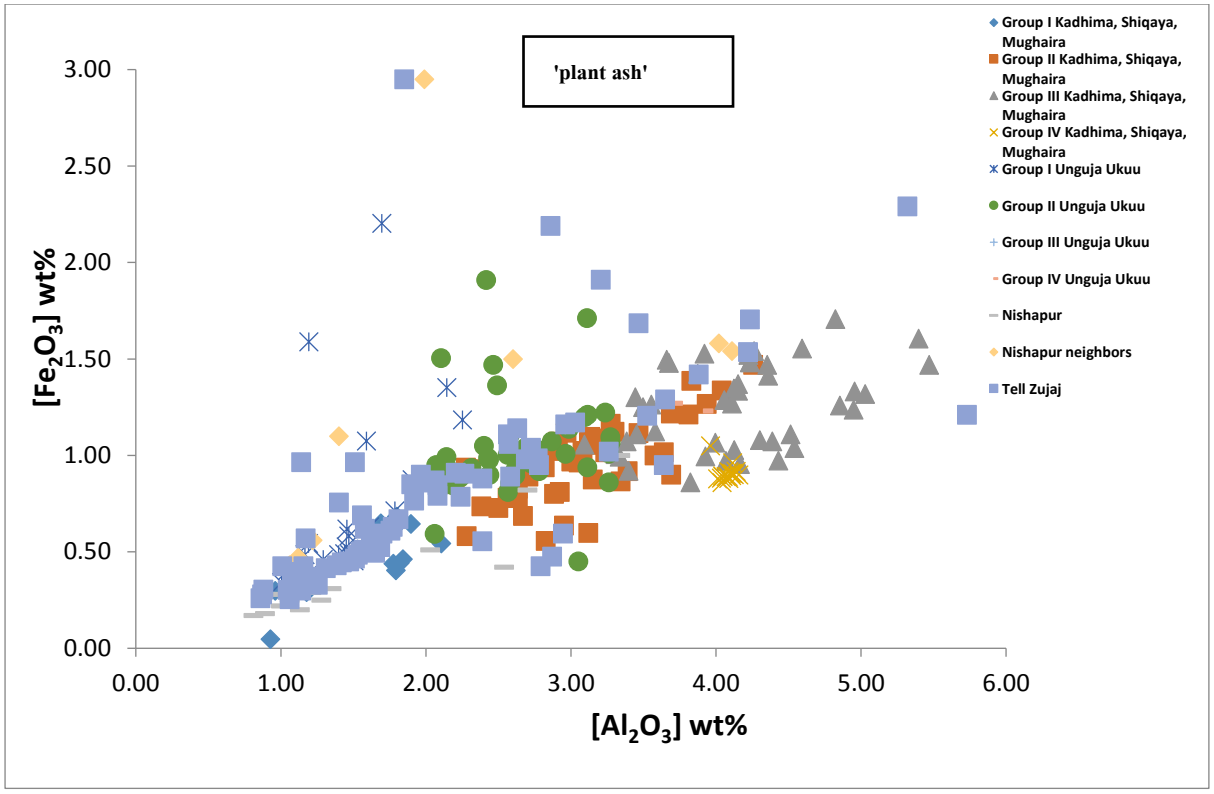


Figure 6.3.4.3: *Plot of aluminium versus iron for all analyzed plant ash glasses from Kadhima, Mughaira and archaeological sites from Nishapur, Nishapur neighbors, Tell Zujaj and Zanzibar.*

samples and ***Group II*** samples from Kadhima, Mughaira, Shiqaya and Unguja Ukuu according to their relative lime and magnesium levels. In this figure, both elements appear more tightly correlated in their concentration with glasses from the Syrian region and clearly distinct from glasses produced in Iraq/Iran that fall below the right part of the graph and ***Group II*** samples that lie upper on the right part of the graph. That complication which applies to ***Group IV*** samples is not observable in the next ***Figure 6.3.4.3.*** The figure illustrates that when alumina and iron content compared there is a clear distinction between ***Group IV*** samples having higher alumina and lower iron and ***Group II*** samples from Kadhima, Mughaira, Shiqaya and Unguja Ukuu having clear lower alumina and higher iron content. This clearly shows that different sand sources were used to make the glasses. However, the comparison in ***Figure 6.3.4.1*** and in ***Figure 6.3.4.2*** point out the problem that can arise when comparing only elements and can be led to two quite different interpretations. For that matter, it would be helpful to carry out additional comparisons such as in ***Figure 6.3.4.3*** to see if the situation can be clarified.

6.3.5 Summary of Kadhima, Mughaira and Shiqaya results

The investigation presented here reveals the sources of early Islamic glass from Kadhima, Mughaira and Shiqaya in the Persian Gulf. In the first instance, the investigation shows that the mineral-soda glasses at Kadhima and Mughaira originated from the same silica source, given that the lime and alumina concentrations are diagnostic of the silica source, and the similarity of alumina and lime concentrations strongly imply the same silica source. But this is not the case for the plant ash soda glass that comprises the majority of the samples; the division into four subtypes with different alumina and lime concentrations (here designated as ***Group I***, ***Group II***, ***Group III*** and ***Group IV***) reveals the use of different silica and plant ash sources. It is important to note that the division suggests probable different origins.

By comparing major oxides and using the results of previous scientific research (major, minor, trace elements and isotopes) of Middle Eastern plant ash glass, there is evidence, direct or indirect, to indicate their origin. The ***Group I*** glasses are chemically similar to Iran/Iraq glass. This category contains glass from Ctesiphon, Sāmarrā, Sīrāf, Nishapur and the surrounding area. In contrast, ***Group II*** is similar to glasses produced in a different zone or location. There is a clear similarity with glasses found in northern Syria (al-Raqqa) and Zanzibar (Unguja Ukuu). A word, finally, about the most important groups (***Group III*** and ***Group IV***). They do not resemble glass found in known contemporary early Islamic sites.

6.4 Chemical characterisation of early Islamic vessels from Unguja Ukuu

Chemical composition analysis has been carried out on 106 glass samples from Unguja Ukuu (*Figure 6.4.1.*,Blair,2016:27) using an electron microanalysis (EPMA) to determine the origin of glass and trade relationships. The samples were analysed at 20kV to determine the major and minor elements. Average concentrations of major and minor elements with standard deviations (errors) are reported in **Table 6.12 (Appendix 4)**. The results were checked against Corning Museum B ancient glass standard. The major and minor elements indicate that the glasses from Unguja Ukuu are soda-lime-silica ($Na_2OCaO\text{-}SiO_2$) glasses typical of late Byzantine and early Islamic glass. **Table 6.13** illustrates that silica is typically in the range of 70%, the lime typically in the range 8% and the alumina contents of about 3%. The majority of glasses (n=85) are of composition made from a combination of ashed halophytic plants and sand. Only 21 samples are soda-lime-silica glasses with low potash and magnesia (average MgO and K_2O <1 wt %).



Figure 6.4.1: *Unguja Ukuu on the east African coast (created by Andrew Blair) (Blair,2016:27).*

Table 6.13 Major element compositions of selected soda-lime-silica glasses.

Oxide	*Glass Groups*	
	Type I Plant ash	***Type II Natron***
(n)	85	20
SiO_2	63.72	68.54
Al_2O_3	2.55	2.79
FeO	1.06	0.56
MnO	0.99	0.03
MgO	**3.91**	**0.54**
CaO	7.70	8.26
Na_2O	14.85	13.25
K_2O	**2.54**	**0.52**

Table 6.13 illustrates how glass from Unguja Ukuu may be divided, according to K_2O and MgO concentrations, into two main groups. ***Type I*** glasses have potash and magnesia levels greater than 1.5wt% and ***Type II*** less than 1.5%. The distinction of the Unguja Ukuu samples into two groups based on potash and magnesia concentrations is illustrated in the plot of K_2O versus MgO, shown in *Figure 6.4.2*. More information about the distinction can be found on page 232.

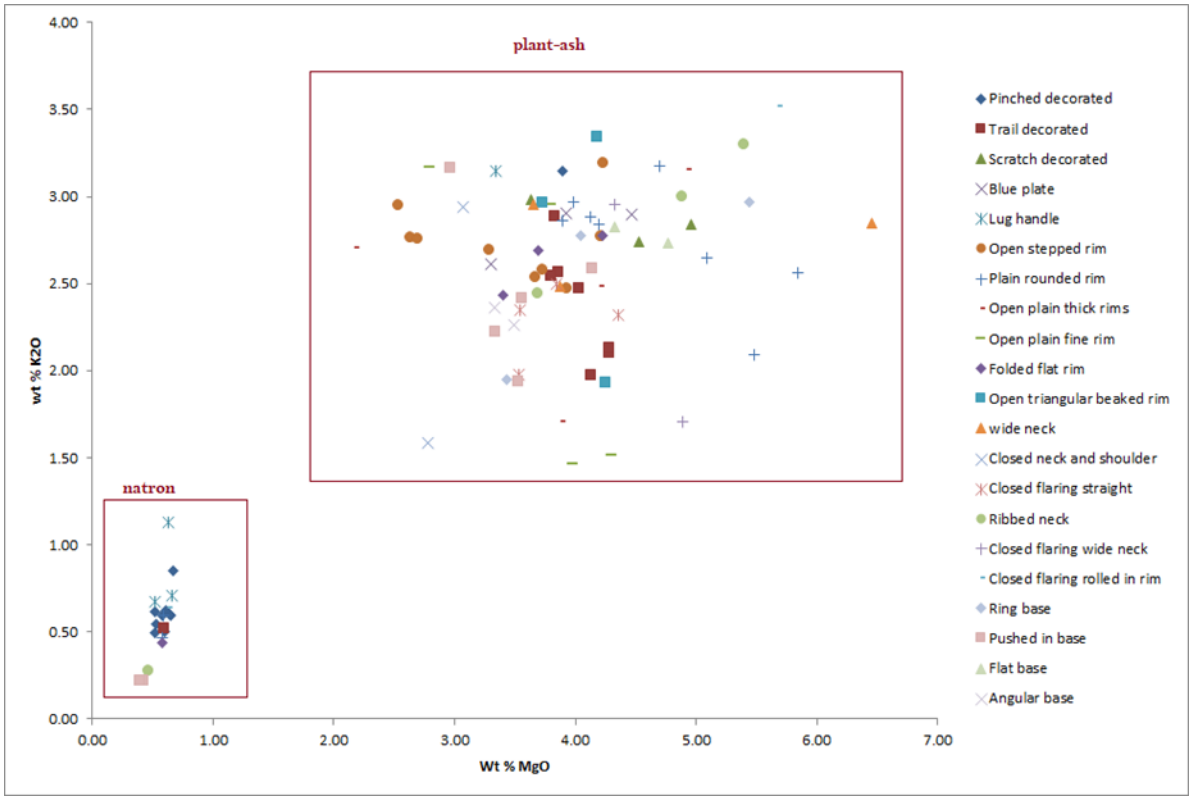


Figure 6.4.2: *K_2O versus MgO (wt%) for the glasses from Unguja Ukuu presented in this study.*

Because it may be some correlation between specific types and forms with the two groups 106 samples were divided into different types and forms. It can be seen in ***Figure 6.4.2*** that there is no correlation between type and form with ***Type I*** or ***Type II*** glass. ***Figure 6.4.2*** compares Unguja Ukuu data for potash and magnesium. Most of the Unguja Ukuu data plots in the upper right on the graph having higher than 1.5% K_2O and MgO and will be termed as ***Type I*** plant-ash glass. This supports the view that has been made using plant ash. The trail decorated fragment illustrated in ***Figure 6.4.3*** is high-magnesia glass. The samples on the left on the graph are different with low potash and magnesia below 1.5% and will be termed as ***Type II*** natron glass. Following the standard theory, the samples on the left on the graph they are considered to be mineral soda glasses. The approximate ranges of these types are indicated in two boxes in ***Figure 6.4.2.***



Figure 6.4.3: *High-magnesia trail decorated fragment uncovered during excavations in Unguja Ukuu.*

6.5 Low-magnesia or natron based glass from Unguja Ukuu

General chemical observation

The soda-lime-silica glass comprises 9 samples with pinched decoration (GL0832,GL0715, GL0765,GL0710,GL0764,GL1855,GL0712,GL2933,GL1999), associated with the early Islamic period, 2 push-up bases (GL2290a, GL2290b), 1 applied base (GL0500), 1 trailed and applied fragment (GL2975), 3 lugs-handles (GL2412,GL1770,GL0717), 1 open-splayed rim (GL3254), 2 plain-rounded rims (GL0459,GL1620), 1 closed-flaring neck (GL3386) and 1 ribbed neck (GL1637). With regards to the composition, a comparison of alumina and lime concentrations confirms that all the above glasses, except glass GL3254, can be classified into three major groups based on major oxides (**Table 6.14**). The correlation of alumina concentrations with silica content indicates variations in the silica source (Freestone *et al.*,2000;2002;Tal *et al.*,2004). Given that the lime and alumina concentrations are diagnostic of the silica source, the differences in alumina and lime concentrations strongly imply that early Islamic glasses at Unguja Ukuu originated from more than one silica source.

The first group, ***Group 1***, consists of two push-up bases (GL2290a, GL2290b) and a ribbed-neck (GL1637) with lower levels of Al_2O_3 and high CaO. The majority, ***Group 2***, consists of 16 glasses with high levels of Al_2O_3 and high CaO. All of the pinched decorated fragments(GL0832,GL0765,GL0710,GL0764,GL1855,GL0712,GL2933,GL1999), except one sample (GL0715), belong to this intermediate group. Other samples in this group include a trail decorated vessel (GL2975), one plain-rounded rim (GL1620), two lugs-handles, one closed-flaring neck (GL3386), and one applied-base (GL0500). ***Group 3*** consists of only two samples, a plain-rounded rim (GL0459) and a pinched decorated fragment (GL0715) with higher Al_2O_3 contents. Before elaborating on the glass groups in more detail, it is necessary to comment on the open-splayed vessel rim, fragment GL3254, which has been excluded from the study because its chemical characteristics (silica concentration 23.51%, alumina 0.10% and lime 0.38% concentration) were not identified clearly.

Table 6.14 Major element compositions of low-magnesia soda-lime-silica glasses.

Oxide	Group 1	Group 2	Group 3
(n)	3	15	2
SiO_2	69.43	67.96	71.61
Al_2O_3	**2.07**	**2.81**	**3.67**
FeO	0.77	0.48	0.87
MnO	0.01	0.03	0.03
MgO	**0.42**	**0.55**	**0.62**
CaO	9.10	8.12	8.09
Na_2O	15.86	12.69	13.31
K_2O	**0.24**	**0.55**	**0.67**

Figure 6.5.1. is a bi-plot of CaO versus Al_2O_3 showing the separation of the groups. In *Figure 6.5.1.* it may be observed that lime is elevated in all Unguja Ukuu natron samples (range of 7.5-10%). However, the alumina ranges in low-magnesia glasses are highly differentiated. The differences in alumina composition imply that these glasses were produced separately or at different sites. Alumina concentration in *Group 1* is lower than 2.5%, while in *Group 2* is between 2.5 and 3% and in *Group 3* is greater than 3%. The interpretation that the different groups originated from more than one silica source can be further corroborated by superimposing the data from Unguja Ukuu with the data from different production groups.

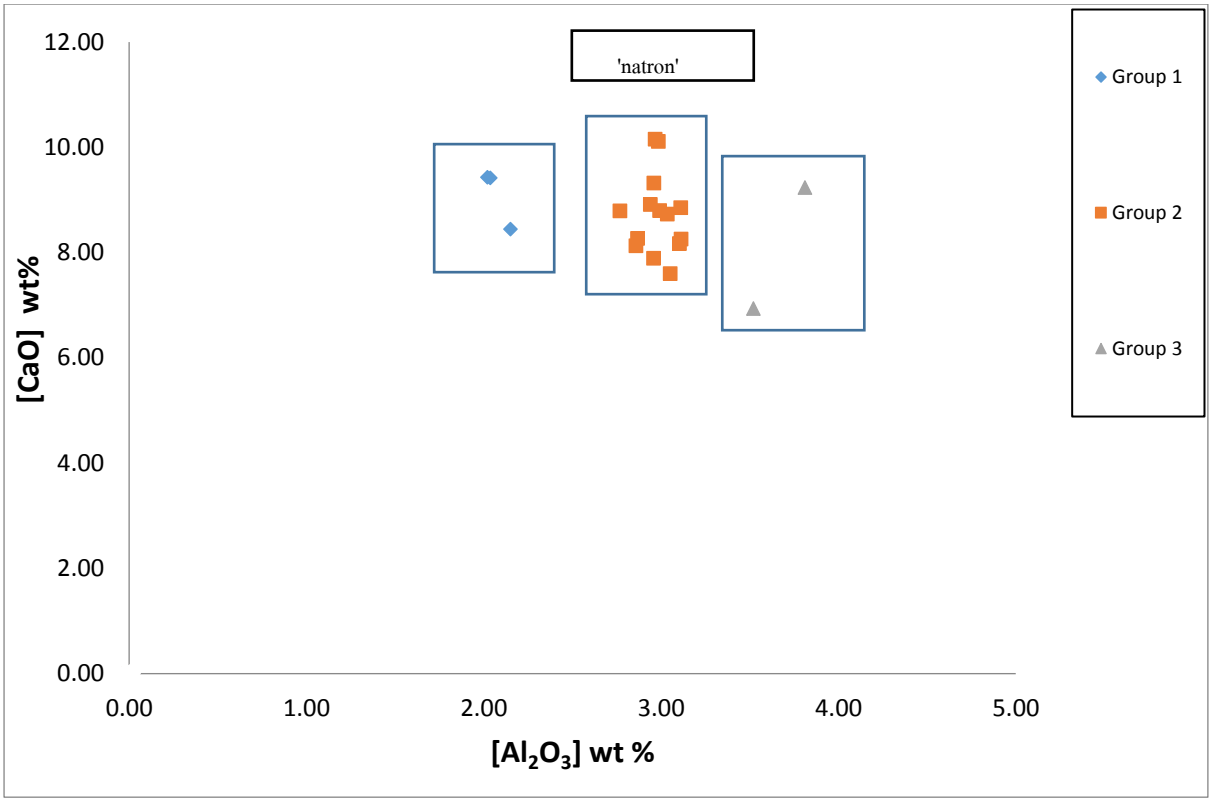


Figure 6.5.1. *Major elements compositions of 20 analyzed low-magnesia glass fragments from Unguja Ukuu. CaO vs Al2O3 plot of natron glass. Lime and alumina oxide content confirm the division of the Unguja Ukuu assemblage into subgroups.*

Figure 6.5.2 compares the Unguja Ukuu samples with ***Levantine I, Levantine II, Egypt I, Egypt II*** and a Levantine source glass. Three glasses from ***Group 1***, two push-up bases and a ribbed neck, with alumina ranges >3% plot on the right of the graph and seem to be associated with ***Egyptian II*** glass. The sixteen samples defined as ***Group 2***, including those with pinched decoration, an applied base, two lugs-handles, a closed-flaring neck and a plain-rounded rim, with alumina ranges around 3% plot on the centre of the graph and seem to be associated with ***Levantine I*** glass (Freestone *et al.*,2000). ***Group 3***, which consists of one plain-rounded rim and a pinched decorated fragment overlaps with alumina ranges greater than 3% plot close to ***Levantine II*** group that is associated with the large-scale manufacturing installations at Bet Eli'ezer, near Hadera in Israel. More information about the concentrations of the production groups see **Table 6.4** (page 237).

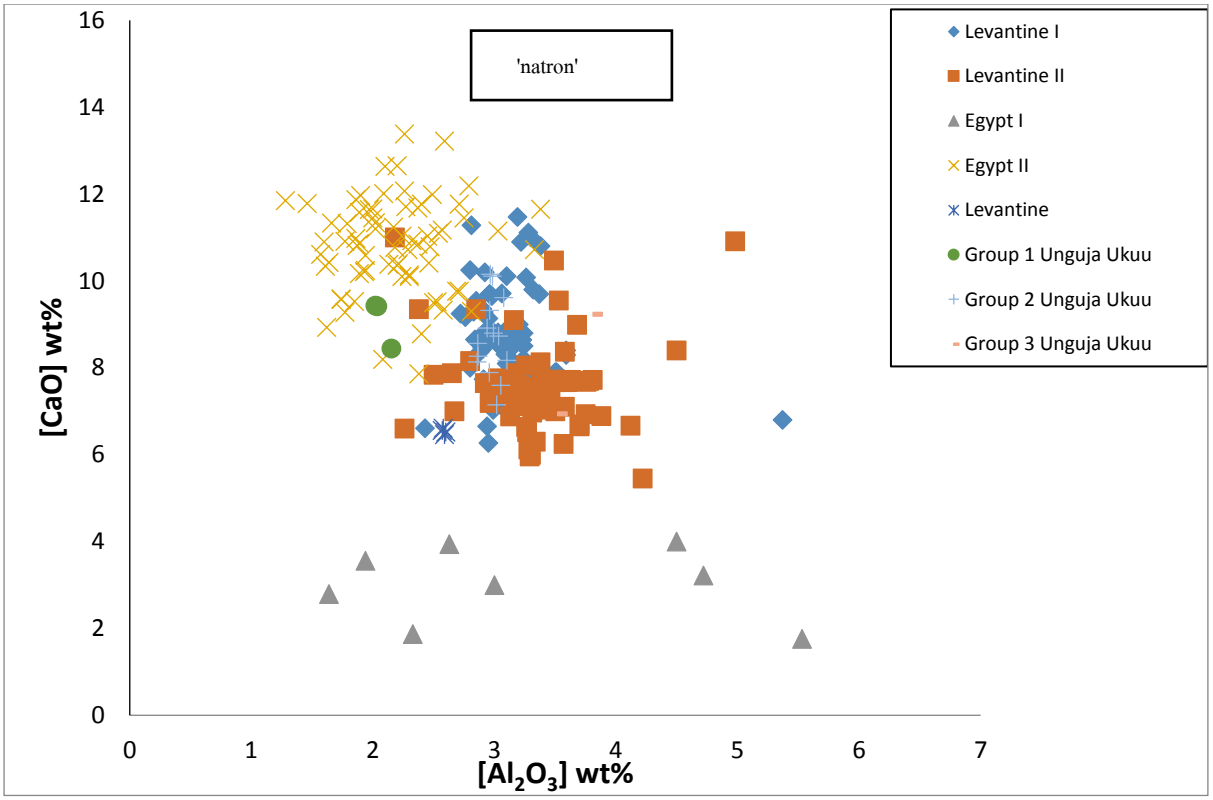


Figure 6.5.2. *Zanzibar group glasses in comparison with contemporary glass production groups. The lime and alumina concentrations of the early Islamic samples from three groups of Unguja Ukuu were compared with the data of contemporary glass types; Levantine I glass from Apollonia, Dor, Jalame, Ramla, al Raqqa and Bet Shean; Levantine II glass from Bet Eli'ezer, Tel Aviv, Raya,* monastery of Wadi al-Tur*; Unknown source from chunk and vessels found at an early Islamic workshop in Tel Aviv; Egypt I from Wadi al-Natrun and Egypt II from Fusṭāṭ , El-Ashmunein and the monastery of Wadi al-Tur.*

To further interpret the data, the majority of the studied samples from Unguja Ukuu, that belong to the group referred to here as ***Group 2***, were superimposed with those from all the sites (Apollonia, Dor, Ramla, al Raqqa, Bet Shean) of the ***Levantine I*** group (***Figure 6.5.3***). The plot of alumina oxide versus lime shows that all the samples from Unguja Ukuu, except one pinched decorated fragment, overlap with the glasses from Ramla (South), and the composition of the assemblages are similar to glass vessels from the Apollonia and with chunks, vessels and waste from Beth Shean. For further examination, low-magnesia glasses from Unguja Ukuu in ***Figure 6.5.4*** compared with two ***Levantine I*** type low-magnesia glasses uncovered at Kadhima and Mughaira.

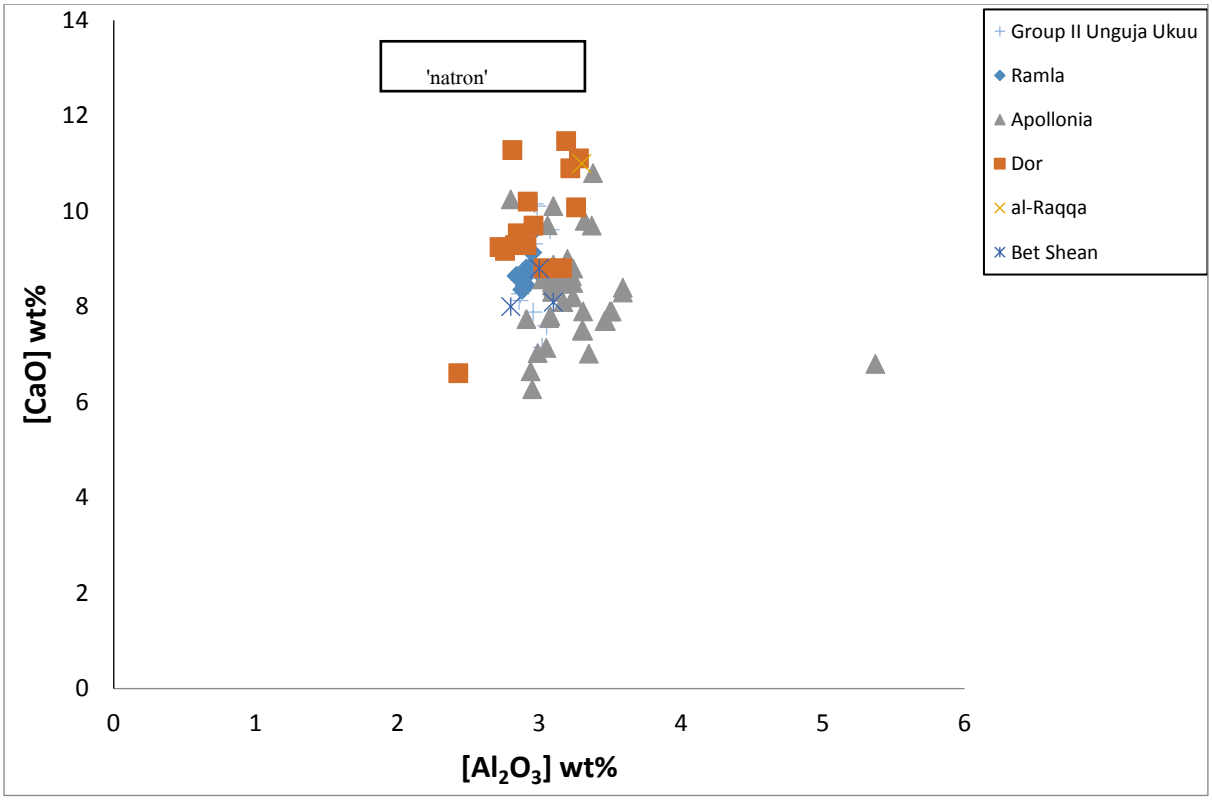


Figure 6.5.3. *The lime and alumina concentrations of the early Islamic samples from Group II Unguja Ukuu (blue cross) were compared with the data of contemporary glass types from Apollonia, Dor, Ramla, al Raqqa and Bet Shean;*

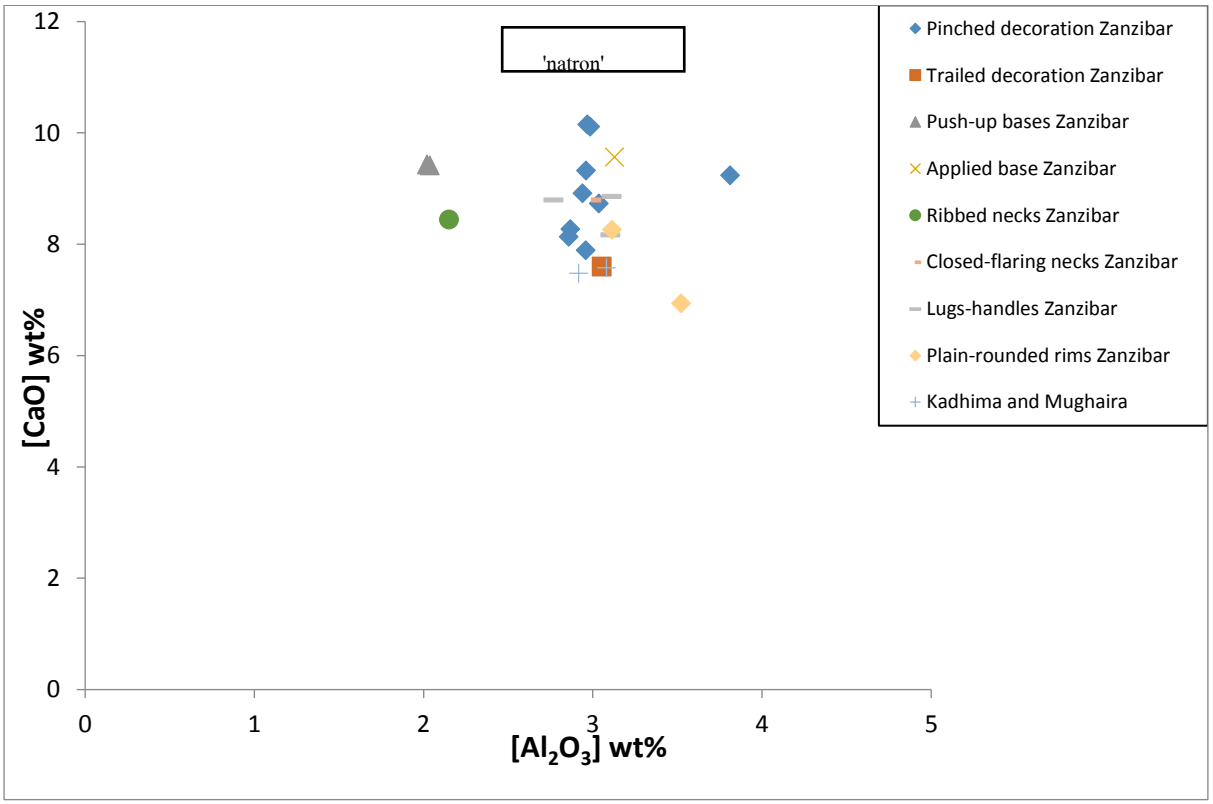


Figure 6.5.4: *Early Islamic natron glass vessels of different type, form and decoration from Unguja Ukuu, Zanzibar in comparison with natron glasses from Kadhima and Mughaira.*

By examing plot in ***Figure 6.5.4***, it appears that the alumina ranges in two natron glasses from Kadhima and Mughaira are greater than 2%; Kadhima and Mughaira glasses plot in the middle of the graph close to ***Group 2*** Unguja Ukuu glasses. The reason that plot close to ***Group 2*** is that shares similarities as opposed to ***Group 1*** and ***Group 3.*** Previously proposal has been made about the association of the specific natron glasses from Kadhima and Mughaira with ***Levantine I*** Apollonia-Arsuf glass. The similarities in alumina composition between two natron glasses from Kadhima and Mughaira and ***Group 2*** Unguja Ukuu glasses implies that these glasses were probably produced at the same site either in the same workshop or could result of a similar basic recipe. The pinched decorated fragment GL0710 illustrated in ***Figure 6.5.5*** is low-magnesia glass associated with ***Levantine I*** Apollonia-Arsuf glass.



Figure 6.5.5: *Low-magnesia fragment with pinched decoration uncovered during excavations in Unguja Ukuu.*

6.6 Plant ash glass from Unguja Ukuu

General chemical observation

The following presentation deals with the comparisons of 85 samples of flux with plant ash. The comparisons presented in ***Figures 6.6.1*** to ***6.6.6*** show that the samples fall into four relatively discrete compositional groups, designated here as ***Group I, Group II, Group III*** and ***Group IV***, based on their major and minor elements (alumina, lime, sodium, magnesium, potassium and iron concentrations). The bi-plots for both 2 sets of oxides in ***Figures 6.6.1*** to ***6.6.3*** are considered to be the most instructive for the thesis showing the discrete groups. These oxide variations in the Unguja Ukuu glass suggests that the discrete compositional groups correspond to different origins of the glasses. **Table 6.15** shows the average concentrations of each plant-ash group. Then, the present data from Unguja Ukuu, Zanzibar, will be compared with data published by Robert Brill, Ian Freestone, Julian Henderson and their colleagues. For more information about the comparative data see subchapter **6.1** (p.232).

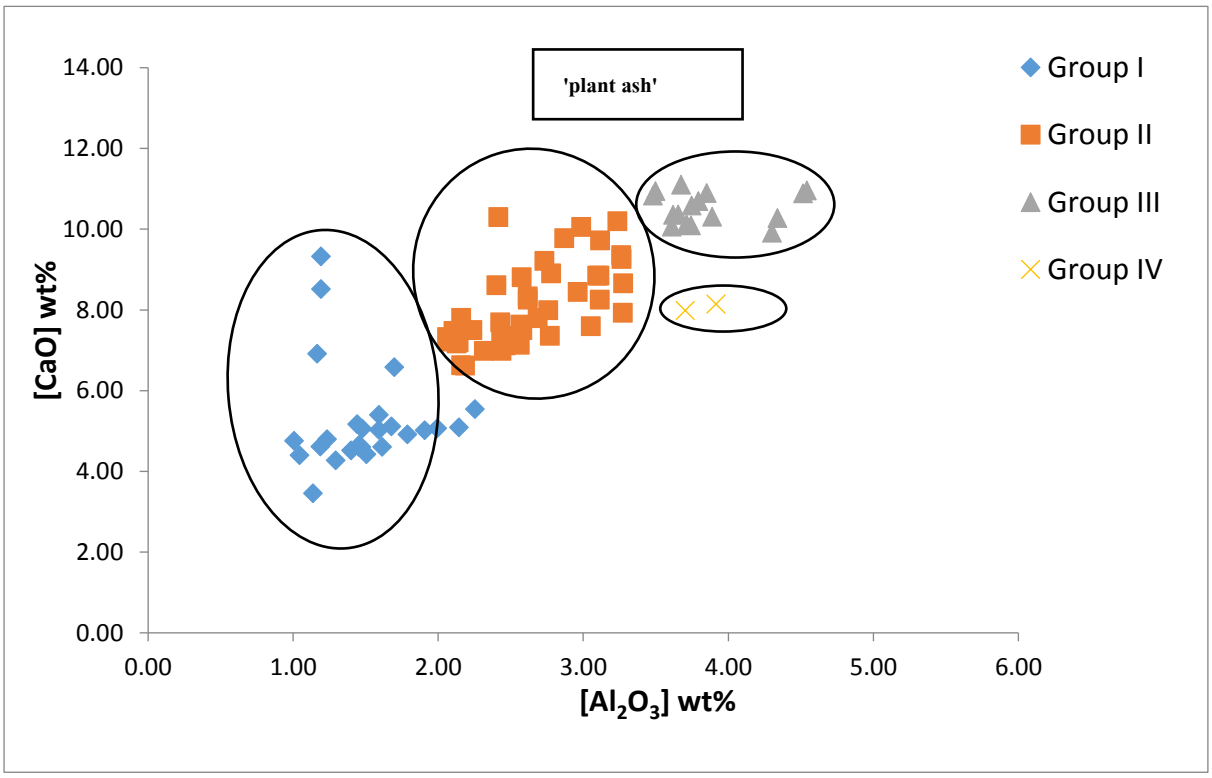


Figure 6.6.1: *Plot of lime versus alumina for all analyzed plant ash glasses from Unguja Ukuu, Zanzibar.*

Table 6.15 Major element compositions of plant-ash soda-lime-silica glasses.

Oxide	Group I	Group II	Group III	Group IV
(n)	26	41	16	2
SiO_2	67.19	63.23	58.96	61.53
St.Dev.	3.16	3.07	1.79	1.51
Al_2O_3	**1.46**	**2.65**	**3.92**	**3.8**
St.Dev.	**0.33**	**0.39**	**3.7**	**0.16**
FeO	0.82	1.04	1.51	1.25
St.Dev.	0.69	0.26	0.17	0.03
MnO	0.49	1.37	0.61	3.23
St.Dev.	0.56	0.84	0.74	1.13
MgO	**4.72**	**3.44**	**4.05**	**3.14**
St.Dev.	**0.97**	**0.98**	**0.32**	**0.54**
CaO	**5.31**	**8.13**	**10.53**	**8.00**
St.Dev.	**1.38**	**1.02**	**0.38**	**0.11**
Na_2O	14.64	15.01	14.9	14.58
St.Dev.	0.96	0.82	0.67	0.41
K_2O	**2.76**	**2.50**	**2.35**	**1.80**
St.Dev.	**0.44**	**0.61**	**0.49**	**0.28**

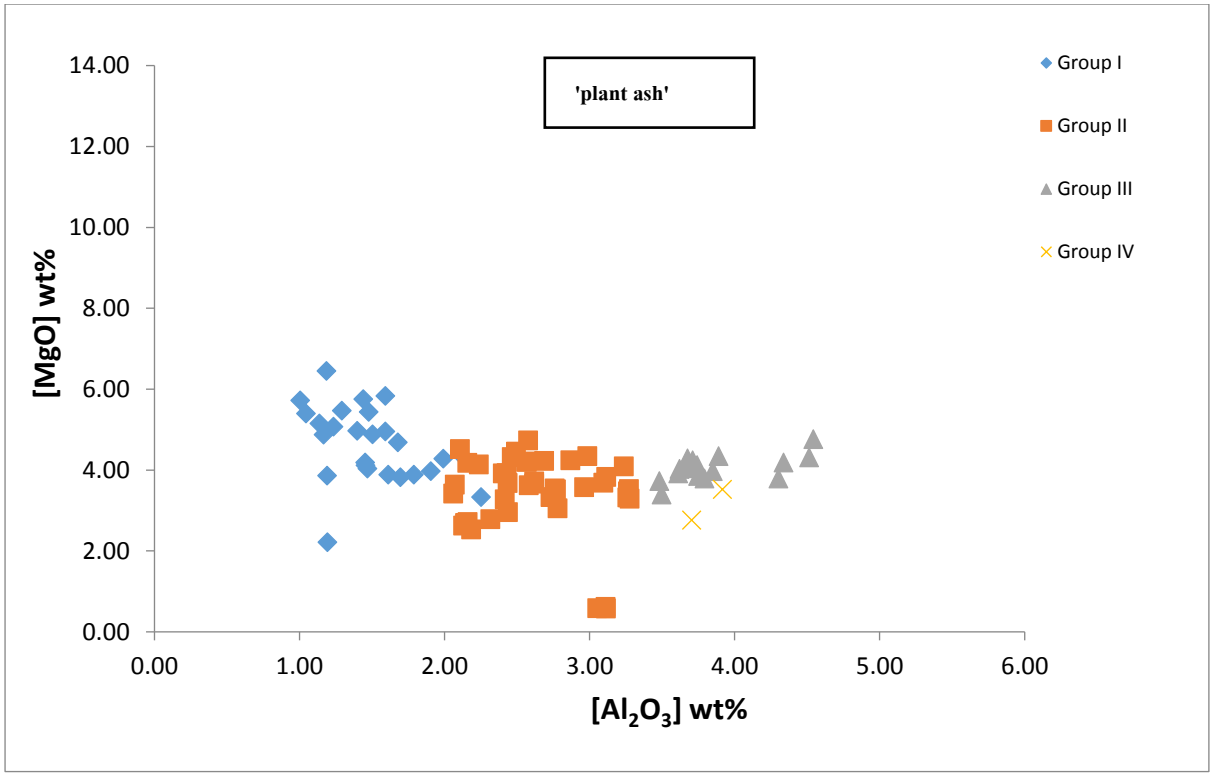


Figure 6.6.2: *Plot of alumina versus magnesium for all analyzed plant ash glasses from Unguja Ukuu, Zanzibar.*

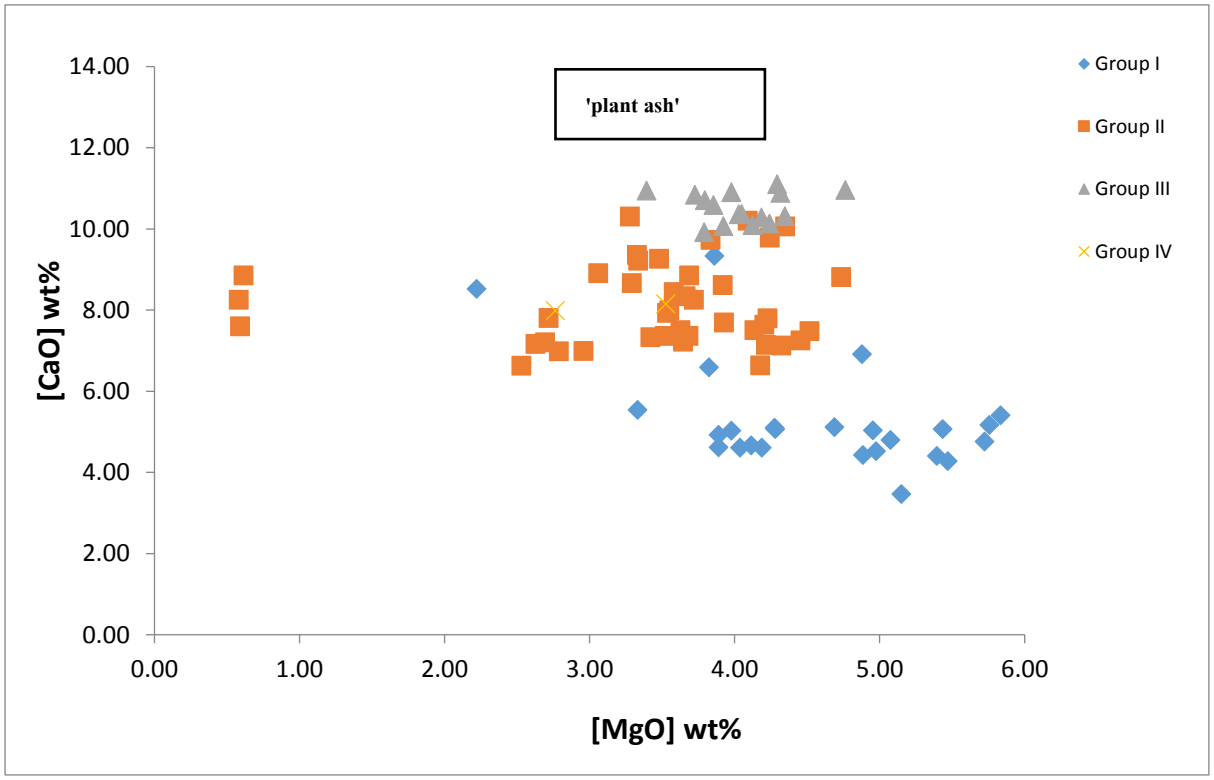


Figure 6.6.3: *Plot of magnesium versus lime for all analyzed plant ash glasses from Unguja Ukuu, Zanzibar.*

In ***Figure 6.6.1,*** the ellipse marked '***Group I***' shows that its glasses differ from ***Group II***, ***Group III*** and ***Group IV*** glasses in terms of the concentration of alumina and lime. More analytically, ***Group I*** has alumina lower than 2% and lime mainly 4-6% and differs from ***Group II*** that having lower than 3% Al_2O_3 and mainly lower CaO; it also differs from ***Group III*** and ***Group IV*** that having greater than 3 Al_2O_3 and greater than 6% CaO. Scientists have explored the raw materials of the early Islamic glass and suggest that alumina and lime concentrations may be used to provide an initial impression of glass groups. Each group is assumed to a different site or recipe. It can be observed in ***Figure 6.6.1*** and ***Figure 6.6.2*** that ***Group III*** contains 16 glasses having the highest Al_2O_3 ratios unmatched by any data we know from sites in the early Islamic world. There is as yet no experimental data to explain the high alumina levels and to be comparable to ***Group III*** glasses.

Figure 6.6.2 is a bi-plot of weight of the magnesium versus alumina indicating that all groups are well distinguished in addition to magnesium concentration. It can be observed in ***Figures 6.6.3*** that lime composition is different in most of the groups. The bi-plot in ***Figures 6.6.3*** shows that the highest lime concentration of ***Group III*** is distinctive. The lime ranges of ***Group III*** are elevated <10% in all the glasses. The reason for the high lime values in ***Group III*** glasses is not known at this time. In reference to previous chemical and trace element analysis ***Group III*** glasses cannot be attributed to primary workshops in Iran or Iraq. It was proved scientifically that Iraqi and Iranian glass has the lowest CaO levels. Furthermore, ***Group III*** glasses cannot be attributed either to Syrian or Levantine glass that has lime above 10%. ***Group III*** glasses could have been the product of different site or different basic recipe. In a chemical analysis sense, alumina, lime and magnesium are not always enough to provide meaningful compositional groupings (Freestone,2002:70;Degryse *et al.*,2010:87). By incorporating bi-plots of more elements it may be essential for our understanding of the above compositional groupings. ***Figures 6.6.4 --6.6.6*** show more comparisons.

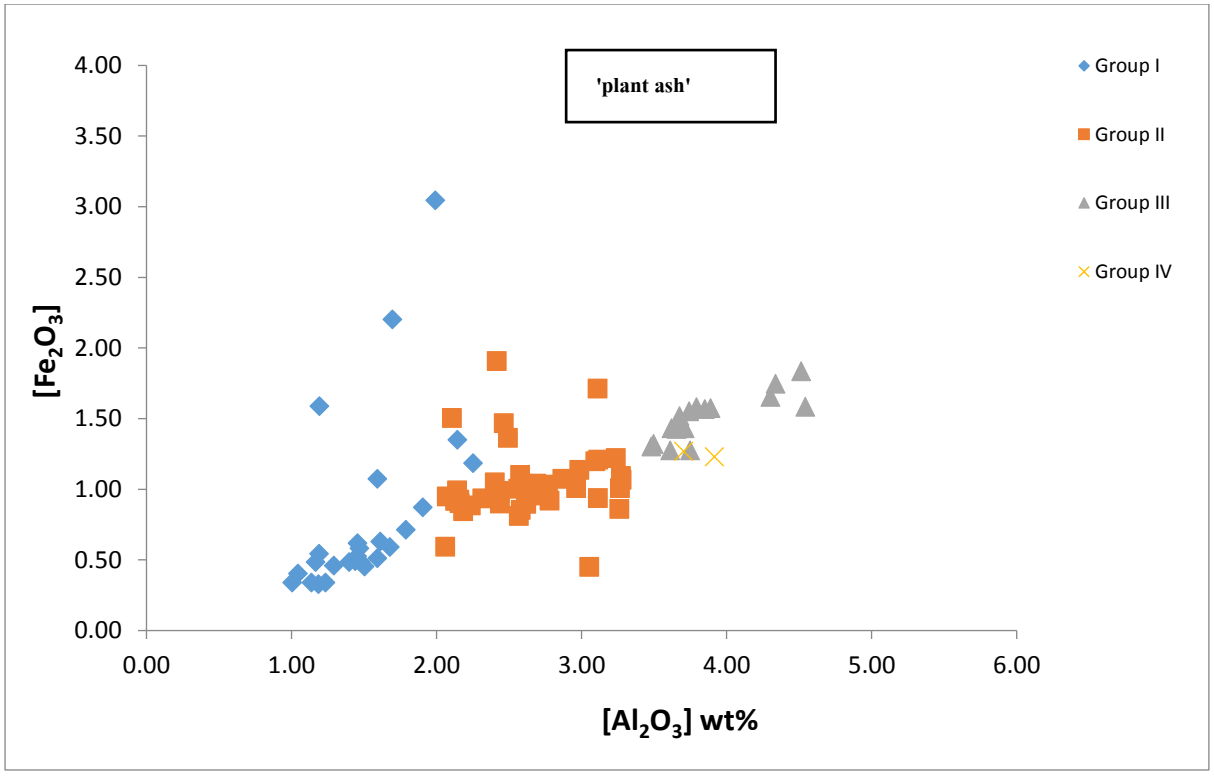


Figure 6.6.4: *Plot of alumina versus iron for all analyzed plant ash glasses from Unguja Ukuu, Zanzibar.*

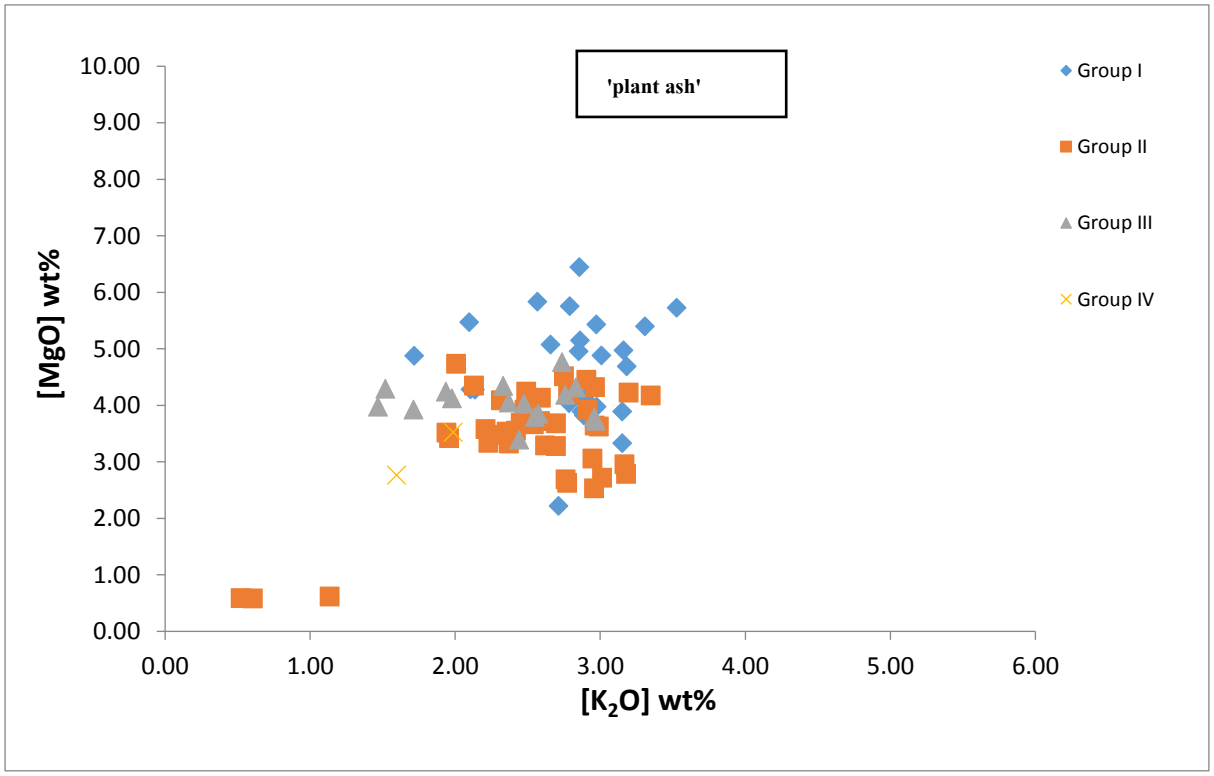


Figure 6.6.5: *Plot of potassium versus magnesium for all analyzed plant ash glasses from Unguja Ukuu, Zanzibar.*

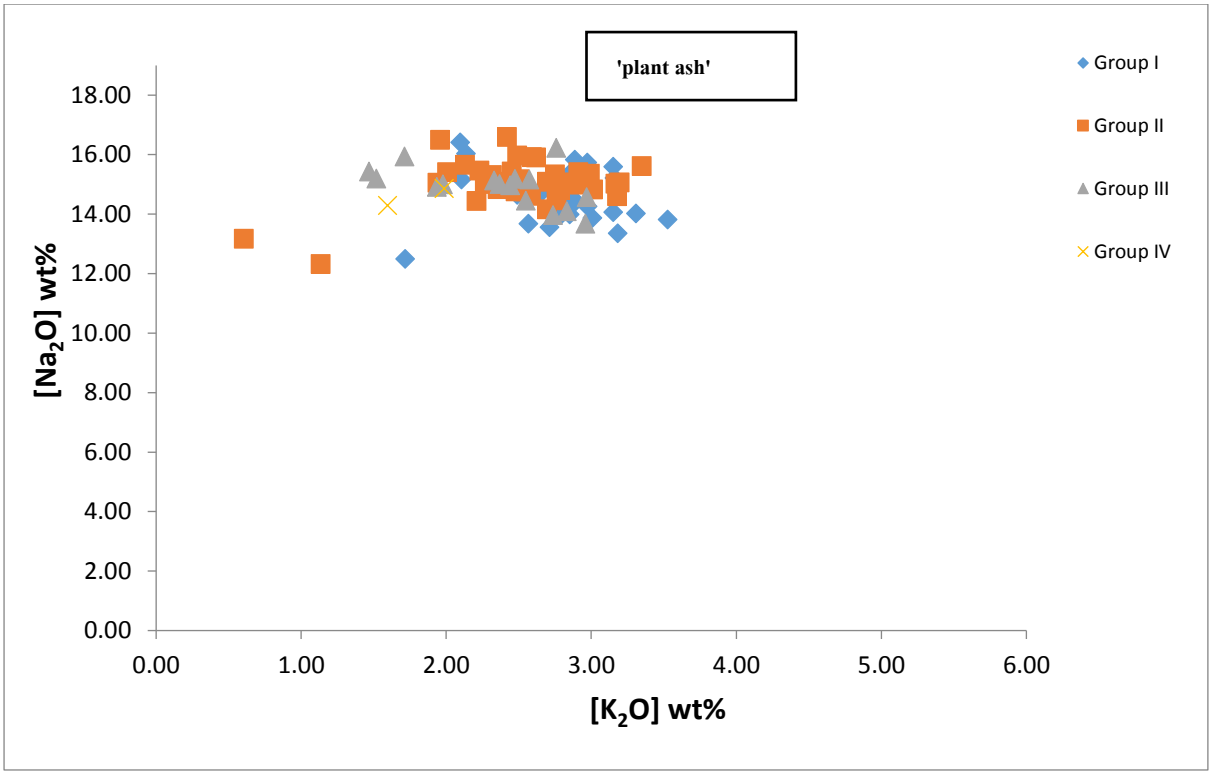


Figure 6.6.6.*: Plot of potassium versus sodium for all analyzed plant ash glasses from Unguja Ukuu, Zanzibar.*

An additional clear distinction of the groups is indicating in F***igure 6.6.4.*** It can be observed in the graph that ***Group I*** has the lowest iron ranges and ***Group III*** has the highest. The iron ranges are less than 2% in ***Group I*** which *means more* elevated than ***Group III***, which are above 4%. This implies to a different site of production or a different recipe. The bi-plots in ***Figures 6.6.4 - 6.6.6,*** a plot of potassium versus magnesium and sodium shows not a clear distinction between the groups, especially in the concentration of sodium. However, it can be observed in ***Figures 6.6.5 - 6.6.6*** that ***Group I*** and ***Group II*** slightly differs from other groups having lower sodium concentration. In ***Figure 6.6.5,*** it can be seen that some ***Group I*** glasses have the highest magnesium levels. All the groups have potassium and sodium values that do not vary considerably. Potassium versus sodium or magnesium cannot be very useful Unguja Ukuu plant ash glasses. ***Group I***, ***Group II***, ***Group III*** and ***Group IV*** are generally similar to potassium and sodium values and this is something to be expected as those elements are not discriminatory. In any event, ***Figures 6.6.5 - 6.6.6*** cannot be utilized for confirming the distinction between ***Group I***, ***Group II***, ***Group III*** and ***Group IV*** or for confirming probable locations of production.

6.6.1 Group I high-magnesia or plant-ash glass

The first group in this study, ***Group I***, is comprised of 26 vessels, having the lowest relative concentrations of alumina, ranging from 1.04% to 2.25%, and lime concentrations ranging from 3.46% to 9.33% (***Table 6.16***). The overall assumption is that levels of lime below 8% and alumina below 2% must have an Iraqi or Iranian source (Henderson *et al.*,2016:138). Using this as a guideline, 26 samples containing the above levels of calcium and aluminium will be compared, as ***Figures 6.6.1.1-6.6.1.3*** show, with samples of similar compositional types from Iraq (six archaeological sites) and Iran (three archaeological sites) dated back to the Sasanian or early Islamic period. Presumably the Iraqi and Iranian samples will be closely related. Before proceeding to the results, it should be mentioned that ***Group I*** comprises glasses of the following types that are clearly distinguishable from the others having the lowest concentrations of lime: eight plain-rounded rims (GL1853, GL0889, GL119, GL1618, GL2723, GL0079, GL1030, GL 1747), one scratch-engraved (GL0090), one pinched (GL0470), one rolled-in rim (GL2616), one closed flaring rolled-in (GL3198), two ribbed-narrow necks (GL1638, GL0949), two ring bases (GL1046, GL1044), one wide neck (GL0143), one thick open plain (GL2980), one open inward-folded rim (GL0190). ***Group I*** also comprises one trail decorated sample that is divided into the body and the trail (GL0213a, GL0213b) and a lug handle. These vessels appear to originate close to Sāmarrā but there is no indication as to whether they belong to Sāmarrā or somewhere else. Two glasses resemble glasses from Sīrāf . Finally, it should be noted that a trail decorated fragment was produced at Ctesiphon (GL3461), which resembles a closed and semi-open flaring straight type. Three Iranian sites were also chosen for comparison of a fragment with a wide neck and a thick open plain (GL382, GL1741) that was produced at Ctesiphon, and a closed flaring wide fragment (GL 3387) that resembles the colourless cut facetted vessels that were produced at Nishapur having low aluminium (0.93%), low magnesium (3.30%) and high silica (72.84%) concentrations. ***Figures 6.6.1.1-6.6.1.6*** show the comparisons.

Table 6.16. Group I glasses resemble glasses from Iraq/Iran.

Sample	Type	Group	Type/form	Resemblance
GL 0090	Plant-ash	Group I	Scratch-engraved	Sāmarrā
GL 0470	Plant-ash	Group I	Pinched	Sāmarrā
GL 1853	Plant-ash	Group I	Plain-rounded rim	Sāmarrā
GL 0889	Plant-ash	Group I	Plain-rounded rim	Sāmarrā
GL 119	Plant-ash	Group I	Plain-rounded rim	Sāmarrā
GL 1618	Plant-ash	Group I	Plain-rounded rim	Sāmarrā
GL 2723	Plant-ash	Group I	Plain-rounded rim	Sāmarrā
GL 0079	Plant-ash	Group I	Plain-rounded rim	Sāmarrā
GL 1030	Plant-ash	Group I	Plain-rounded rim	Sāmarrā
GL 1747	Plant-ash	Group I	Plain-rounded rim	Sāmarrā
GL 2616	Plant-ash	Group I	Rolled in rim	Sāmarrā
GL 3198	Plant-ash	Group I	Closed flaring rolled in	Sāmarrā
GL 1638	Plant-ash	Group I	Ribbed-narrow neck	Sāmarrā
GL 0949	Plant-ash	Group I	Ribbed-narrow neck	Sāmarrā
GL 1046	Plant-ash	Group I	Ring base	Sāmarrā
GL 1044	Plant-ash	Group I	Ring base	Sāmarrā
GL 0143	Plant-ash	Group I	Wide neck	Sāmarrā
GL 2980	Plant-ash	Group I	Open plain thick	Sāmarrā
GL 0190	Plant-ash	Group I	Open inward-folded rim	Sāmarrā

Sample	Type	Group	Type/form	Resemblance
GL 0213a	Plant-ash	Group I	Trail decorated	close to Sāmarrā ;
GL 0213b	Plant-ash	Group I	Trail decorated	close to Sāmarrā ;
GL 3461	Plant-ash	Group I	Trail decorated	Ctesiphon
GL 802	Plant-ash	Group I	Lug handle	close to Sāmarrā ;
GL 3387	Plant-ash	Group I	Closed flaring wide	Nishapur
GL 382	Plant-ash	Group I	Wide neck	Siraf
GL 1741	Plant-ash	Group I	Open plain thick	Siraf

In *Figure 6.6.1.1* the majority of ***Group I*** samples fall below at the left part of the graph and are plotted close to the Sāmarrā glasses having similar alumina content lower than 2% and lime content between 4 to 5%. It is worth emphasizing that ***Group I*** samples are easily distinguished having lower lime less than 6% and alumina less than 2% from Tell Umm Ghemimi, Jezaziyat, Tell Umm Jirin and Choche glasses. One sample GL3461 has elevated lime 6.59% and is close matches for the Ctesiphon glasses. It is very likely GL3461 and Ctesiphon glasses came from a single region. On the other hand three samples (GL3387,GL382, GL1741) are distinctly different from ***Group I*** samples and lie at the upper left part of the graph having the higher lime content less than 10% and the lower alumina content less than 1.19%. The above samples that form a cluster at the upper left part of the graph has no matching and probably came from a different source. Their alumina and lime ranges are similar to other artifacts of Iranian origin. For that matter, as we will see below, comparison with Iranian sites will follow.

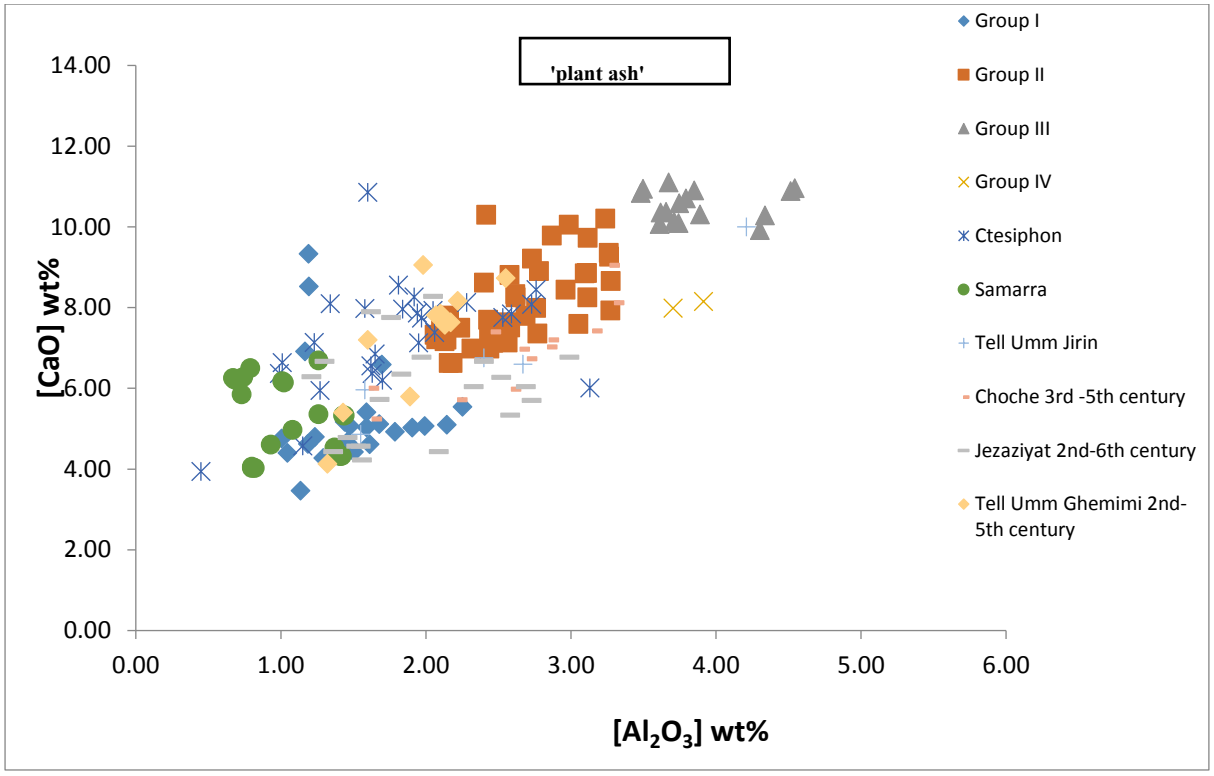


Figure 6.6.1.1: *Plot of alumina versus lime for all analyzed plant ash glasses from Unguja Ukuu and six Iraqi archaeological sites.*

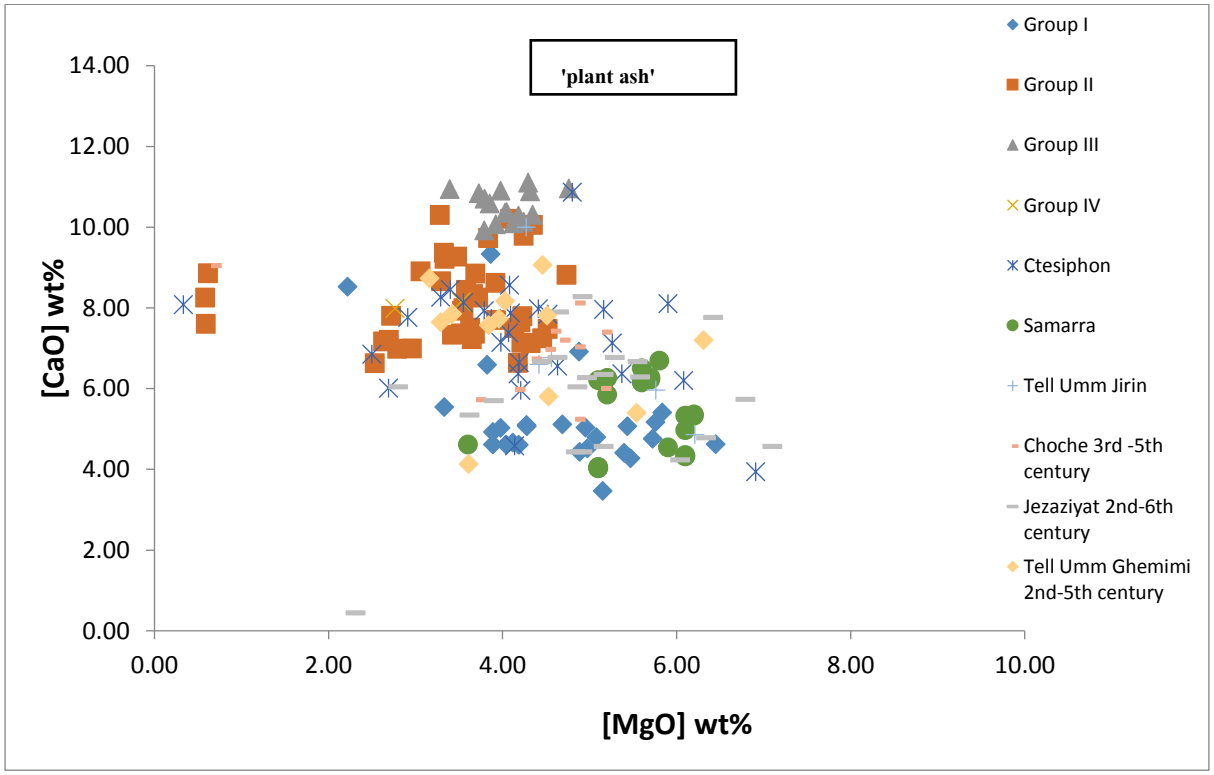


Figure 6.6.1.2: *Plot of magnesium versus lime for all analyzed plant ash glasses from Unguja Ukuu and six Iraqi archaeological sites.*

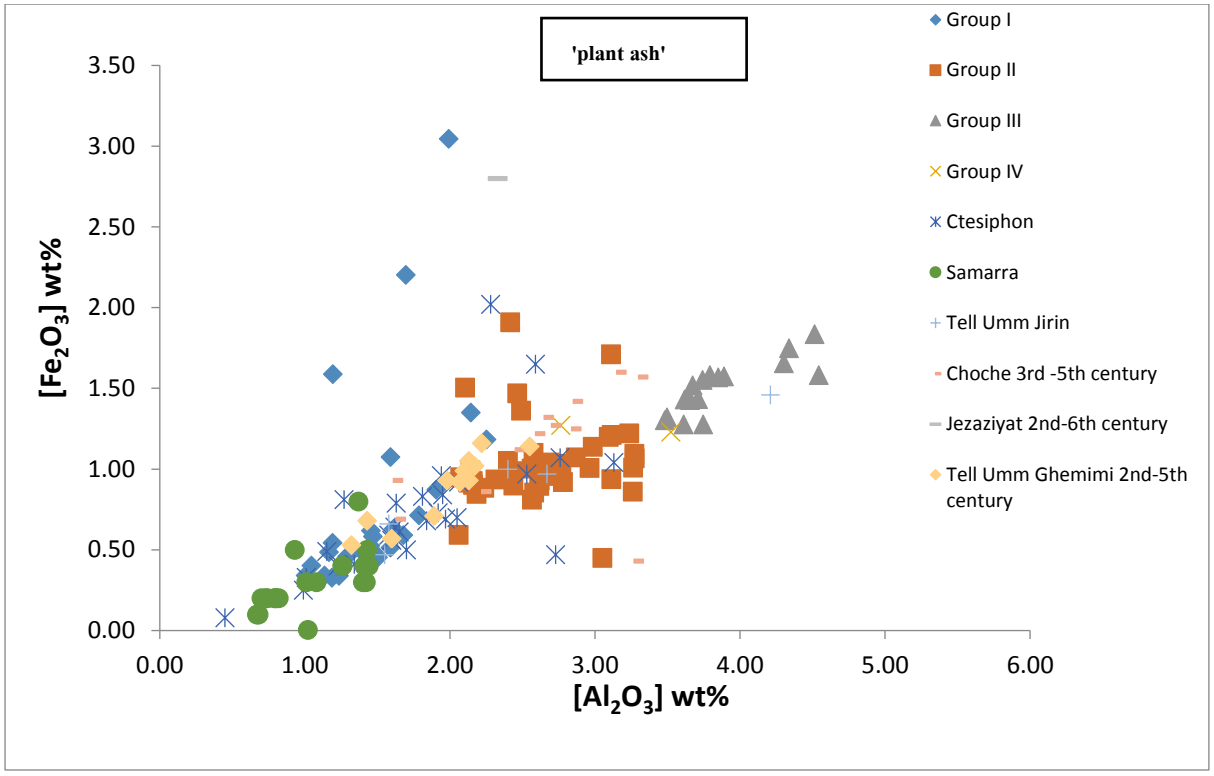


Figure 6.6.1.3*: Plot of aluminium versus iron for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and six Iraqi archaeological sites.*

Figure 6.6.1.2 compares the magnesium versus the alumina ratios, which also may be used to distinguish the majority of ***Group I*** samples from Tell Umm Jirin, Choche, Jezaziyat and Tell Umm Ghemimi glasses. The majority of ***Group I*** samples having magnesium from 3.89 to 6.45% and lime less than 6% fall below in the area at the right of the diagram close to Sāmarrā glasses. The strong correlation between ***Group I*** samples and Sāmarrā glasses correlation were produced at the same site. Four Unguja Ukuu samples were produced separately at different sites; the magnesium level in GL382 and GL1741 is noticeably lower less than 4% and the lime level is high more than 8%. The differences could suggest that the two samples were made in different location. ***Figure 6.6.1.2*** shows that Ctesiphon glasses have similar magnesium content between 3.82 to 6.59% but are distinctly different from ***Group I*** samples having above 5% lime. One sample GL3461 from Unguja Ukuu with 3.82% magnesium has high lime 6.92% and plot between Ctesiphon glasses. There has been previous discussion about sample GL3387 from Unguja Ukuu of its Iranian origin nevertheless in ***Figure 6.6.1.2*** having 4.88% magnesium resemble glasses from Ctesiphon but has lime slightly higher than 6.59%.

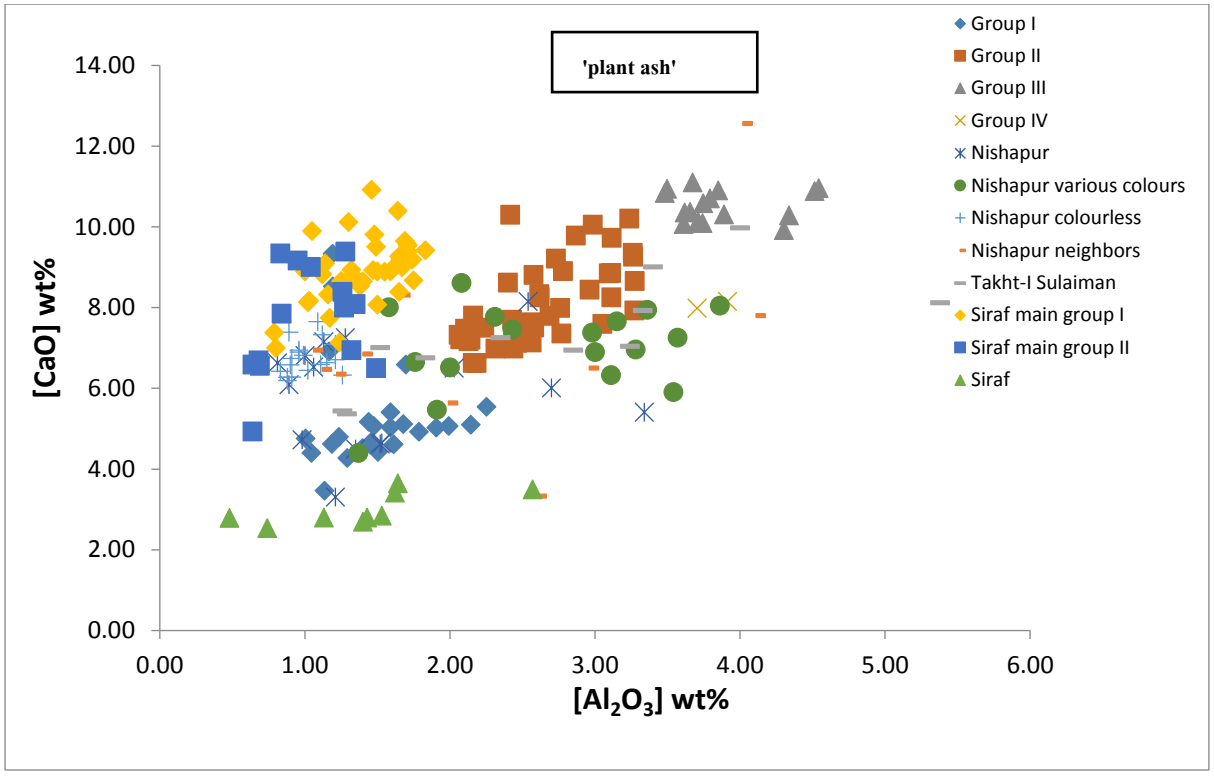


Figure 6.6.1.4*: Plot of aluminium versus lime for all analyzed plant ash glasses from Unguja Ukuu and three Iranian archaeological sites.*

In ***Figure 6.6.1.3*** it can be seen that there is an observable separation between ***Group I*** samples and glasses from Tell Umm Ghemimi, Jezaziyat, Choche and Tell Umm Jirin glasses based on the range of alumina greater than 1.50% and iron greater than 0.50%. ***Group I*** samples seem to fall between the Sāmarrā and Ctesiphon glasses. The majority of Ctesiphon glasses lies upper on the graph having elevated iron content more than 0.50% and alumina greater than 1.50% and is slightly different ***Group I*** samples. ***Group I*** samples are generally closest to the Sāmarrā glasses having the same iron and alumina content. The similarity of ***Group I*** samples and the Sāmarrā glasses in ***Figure 6.6.1.3*** could suggest that these glasses were produced at the same location. ***Figures 6.6.1.1-6.6.1.3*** show that three samples were produced separately at a different site in Iraq/Iran. For the question of whether the three samples were produced in an Iranian site, it will be necessary to add additional comparisons with glasses produced in Iran. For that matter, glasses from three Iranian sites (Nishapur, Siraf, Takht-I Sulaiman) will be compared with Unguja Ukuu glasses in ***Figures 6.6.1.4-6.6.1.6.***

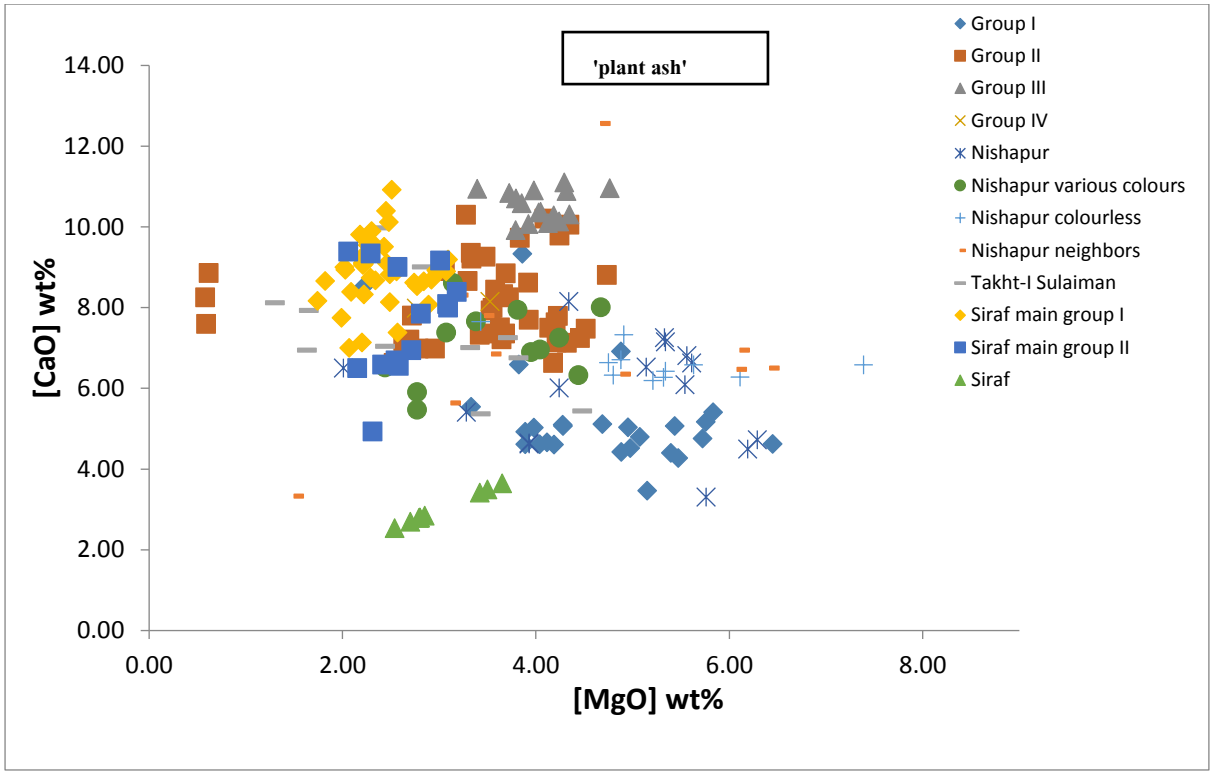


Figure 6.6.1.5: *Plot of magnesium versus lime for all analyzed plant ash glasses from Unguja Ukuu and three Iranian archaeological sites.*

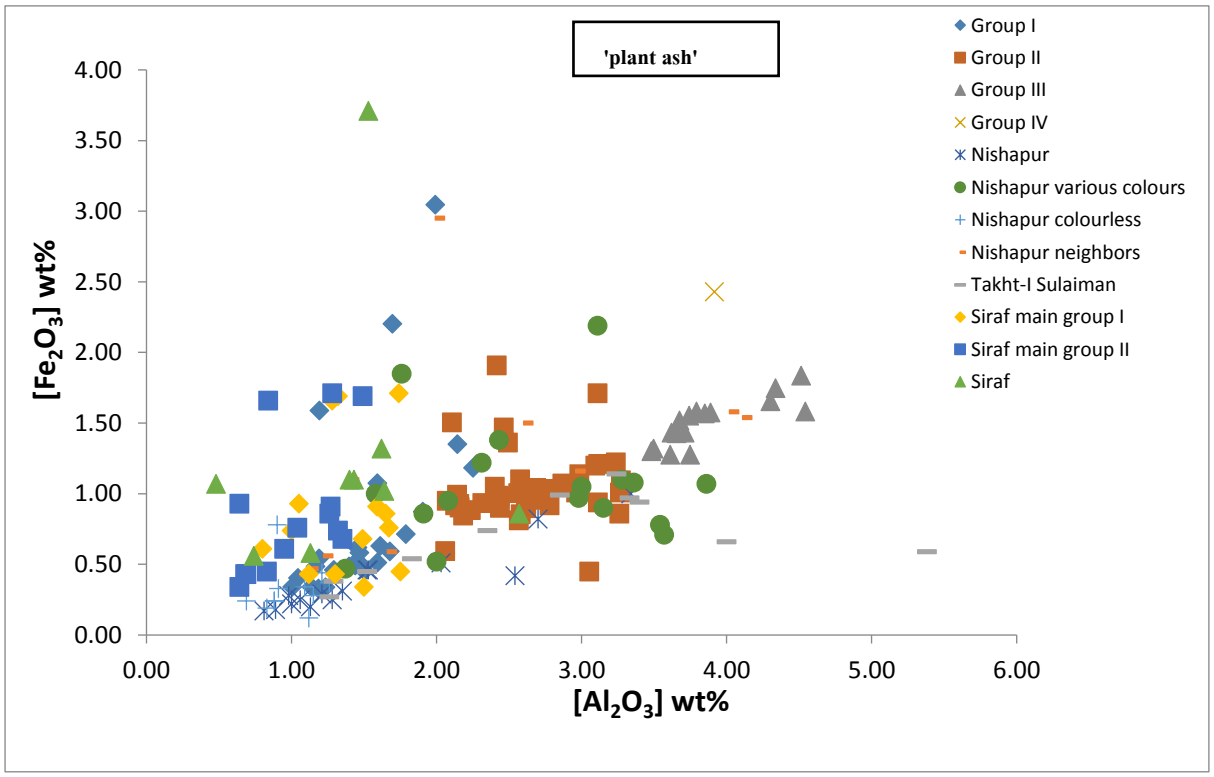


Figure 6.6.1.6: *Plot of aluminium versus iron for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and three Iranian archaeological sites.*

For the question whether three glasses (GL3387,GL387,GL1741) uncovered at Unguja Ukuu were produced separately at an Iranian site, ***Figure 6.6.1.4*** answer the question. In ***Figure 6.6.1.4,*** two samples (GL387,GL1741) plot mainly with Siraf Main group I characterised by lower alumina 1.19% and the highest lime more than 8%. One sample GL3387 is distinctive from Siraf Main group I having lower lime range less than 8%; it can be seen that falls lower from Siraf Main group I to the graph close to a well-defined Nishapur colourless group. The similarity of GL3387 and Nishapur colourless group could suggest that were made at the same location. Surely the similarities between GL387,GL1741 and Siraf Main group I and between GL3387 and Nishapur can be observed in the next figure, ***Figure 6.6.1.5.***

It can be seen that GL3387 falls into distinct Nishapur colourless glass having magnesium 4.88% and high lime more than 6% in contrast with other ***Group I*** samples. The result show that indicate that GL3387 was made in Nishapur. In ***Figure 6.6.1.5.,*** it is observable the similarity in magnesium and lime content between GL387,GL1741 and Siraf Main group I. These two Unguja Ukuu samples having less than 4% lime and greater than 6% lime are far more clearly associated with Siraf Main group I. In ***Figure 6.6.1.6,*** it is difficult to conclude whether three glasses (GL3387,GL387,GL1741) having iron around 0.50% and alumina around 1.18% and plotting between Nishapur colourless glass and Siraf Main group I belong either to the one either to the other group. For that matter, there has been previous discussion of the accuracy and how important are the comparisons of more than two elements.

6.6.2 Group II- high-magnesia or plant-ash glass

Group II in this study comprises the majority of the vessels (n=41) (***Table 6.17***). It is noteworthy that glass from ***Group II*** resembles the chemical composition of al-Raqqa Type 2 glass from Syria, a fact that supports the assumption that Syria was a centre of diffusion (Henderson,1999:438;Henderson et el.,2004:452;Henderson *et al.*,2016:138). ***Group II*** has the compositional characteristics of high magnesia glass from Tell Zujaj, which presents differences from other high magnesia early Islamic glasses. All of the ***Group II*** samples have relatively high aluminium oxide, ranging from between 2.20% to 3.95%, as well as lower magnesium, slightly lower silica, higher iron and manganese oxides than other Islamic glasses (Henderson,1999:436;Henderson *et al.*,2004:444).

The Unguja Ukuu samples will be compared with two archaeological sites from al-Raqqa and one from Damascus dated back to the early Islamic period. The comparison will be shown in ***Figures 6.6.2.1-6.6.2.3***. It is wise to keep in mind that ***Group II*** glass is clearly distinguishable and significantly differs from the assemblages from 11th century AD Tell Fukhkhar and 12th century AD Damascus, but that the ***Group II*** glass positively correlates with Tell Zujaj (Henderson,2004:449-450;Henderson *et al.*,2016:136). The implication of these positive correlations is that ***Type II*** was made in Tell Zujaj from the late 8th to early 9th century AD. Hence, the suggestion is that Tell Zujaj might be the possible place of production for the ***Group II*** glass. Glass of ***Type II*** has also been found in Kadhima, Mughaira, Shiqaya, Zanzibar, Nishapur and Ctesiphon.

In ***Figure 6.6.2.1,*** it can be seen that ***Group II*** samples having higher alumina ranges between 2.17 to 3.10% cluster together at the right part of the graph and can be clearly distinguished from Damascus and Tell Fukhkhar glasses plotting at the left part of the graph having lower than 2% alumina ranges. ***Group II*** samples also differ from Damascus and Tell Fukhkhar glasses in terms of their lime content having lower lime mainly less than 10%. It is worth pointing out that the most noticeable characteristic of ***Group II*** samples is its great dispersion. The lime and alumina values vary widely, covering a range of 2.07 to 3.90 alumina and 6.63 to 10% lime. The wide dispersion leads to different interpretations. It is not known whether the dispersion could result from different raw materials used (use of different plant species or sand) or a different basic recipe.

Table 6.17 Group II glasses resemble glasses from al-Raqqa.

Sample	Type	Group	Type/form	Resemblance
GL 3145	Plant-ash	Group II	Cane mosaic	al-Raqqa, Type 2
GL 2975	Plant-ash	Group II	Applied trail	al-Raqqa, Type 2
GL 2846	Plant-ash	Group II	Scratch-engraved	al-Raqqa, Type 2
GL 2244	Plant-ash	Group II	Scratch-engraved	al-Raqqa, Type 2
GL 0155	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 3450	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 0040	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 0154	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 0038	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 3449	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 0635	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 0943	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 1029	Plant-ash	Group II	Open-stepped rim	al-Raqqa, Type 2
GL 2657	Plant-ash	Group II	Ribbed neck	al-Raqqa, Type 2
GL 1950	Plant-ash	Group II	Open triangular beaked rim	al-Raqqa, Type 2
GL 659	Plant-ash	Group II	Pushed up base	al-Raqqa, Type 2
GL 2293	Plant-ash	Group II	Pushed up base	al-Raqqa, Type 2
GL 2715	Plant-ash	Group II	Pushed up base	al-Raqqa, Type 2
GL 1014	Plant-ash	Group II	Pushed up base	al-Raqqa, Type 2
GL 77	Plant-ash	Group II	Pushed up base	al-Raqqa, Type 2
GL 1226	Plant-ash	Group II	Ring base	al-Raqqa, Type 2
GL 2147	Plant-ash	Group II	Open plate	al-Raqqa, Type 2
GL 2325	Plant-ash	Group II	Open plate	al-Raqqa, Type 2
GL 2677	Plant-ash	Group II	Open plate	al-Raqqa, Type 2

***Table 6.17**. **Group II** glasses resemble glasses from al-Raqqa.*

Sample	Type	Group	Type/form	Resemblance
GL 2689	Plant-ash	Group II	Closed flaring straight	al-Raqqa, Type 2
GL 1633	Plant-ash	Group II	Closed flaring straight	al-Raqqa, Type 2
GL 2857	Plant-ash	Group II	Closed flaring wide	al-Raqqa, Type 2
GL 0904	Plant-ash	Group II	Closed neck and shoulder	al-Raqqa, Type 2
GL 572	Plant-ash	Group II	Closed neck and shoulder	al-Raqqa, Type 2
GL 2097	Plant-ash	Group II	Folded flattened rim	al-Raqqa, Type 2
GL 1339	Plant-ash	Group II	Folded flattened rim	al-Raqqa, Type 2
GL 2450	Plant-ash	Group II	Open-inwards folded rim	al-Raqqa, Type 2
GL 0911	Plant-ash	Group II	Open plain thick	al-Raqqa, Type 2
GL 3338	Plant-ash	Group II	Open flared sided vessel	al-Raqqa, Type 2
GL 1616	Plant-ash	Group II	Open-plain fine	al-Raqqa, Type 2
GL 1620	Plant-ash	Group II	Open-plain rounded rim	al-Raqqa, Type 2
GL 1337	Plant-ash	Group II	Vertical neck wide	al-Raqqa, Type 2
GL 0717	Plant-ash	Group II	Lug handle	al-Raqqa, Type 2
GL 1343	Plant-ash	Group II	Miniature jar	al-Raqqa, Type 2

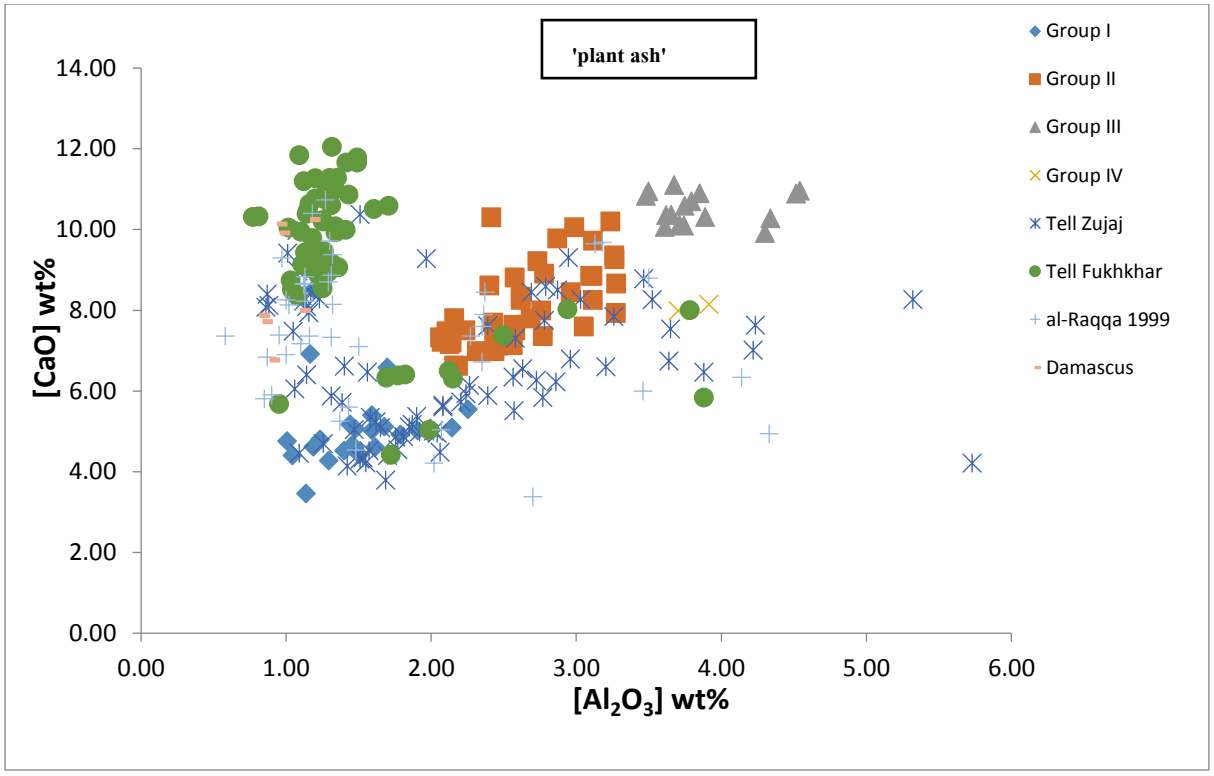


Figure 6.6.2.1*: Plot of aluminium versus lime for all analyzed plant ash glasses from Unguja Ukuu and three Syrian archaeological sites.*

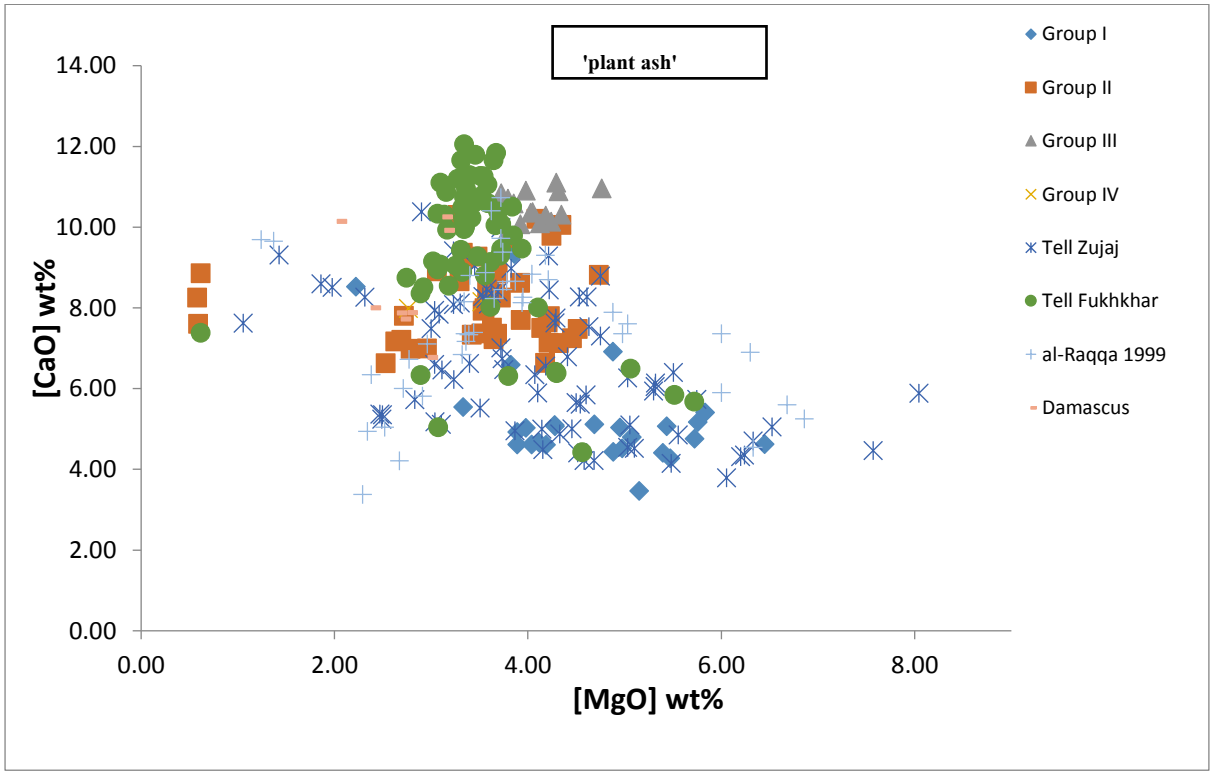


Figure 6.6.2.2*: Plot of magnesium versus lime for all analyzed plant ash glasses from Unguja Ukuu and three Syrian archaeological sites.*

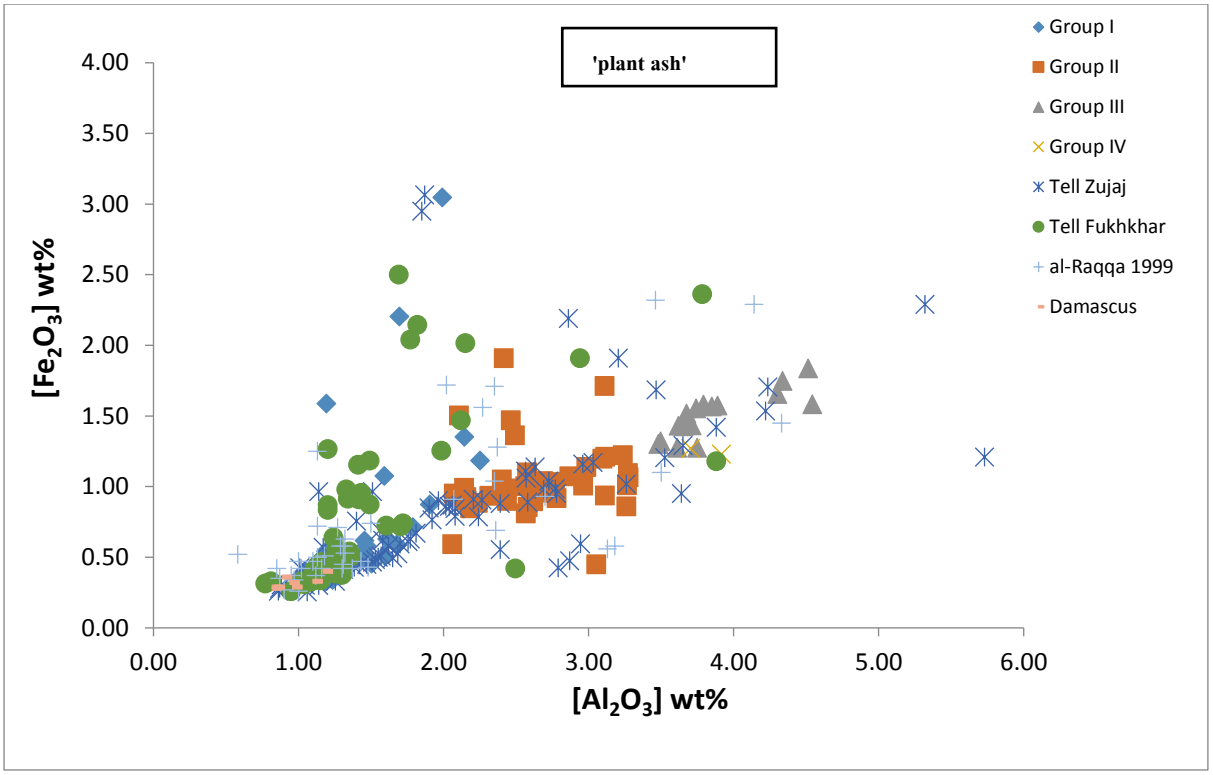


Figure 6.6.2.3*: Plot of aluminium versus iron for all analyzed plant ash glasses from Unguja Ukuu and three Syrian archaeological sites.*

In ***Figure 6.6.2.2, Group II*** samples are plotted lower on the graph than Tell Fukhkhar glasses having noticeably less lime lower than 10% and greater magnesium ranges. It is also noted in ***Figure 6.6.2.2*** that there is no correlation between magnesium and lime among ***Group II*** samples and Damascus glass. The elevated values of magnesium greater than 3% observed at ***Group II*** samples are not apparent in Damascus glasses. However, as we can see in ***Figure 6.6.2.2***, this cannot be concluded for Tell Zujaj glasses that have similar magnesium and lime values with ***Group II*** samples. In ***Figure 6.6.2.3,*** Tell Zujaj glasses are a very close match with ***Group II*** samples having similar iron and alumina values. In Tell Zujaj glasses the concentration of iron oxide varies and can be also similar with glasses from Tell Fukhkhar. It can be observed in ***Figure 6.6.2.3*** that there is no correlation with iron between Tell Fukhkhar and ***Group II*** glasses. In a larger sense, ***Figures 6.6.2.1-6.6.2.3***. show that ***Group II*** samples are closely related with Tell Zujaj glasses and this is a clear indication of the relationship between those glasses. The discussion will follow in the next chapter about the importance of that relationship.

6.6.3 Group III high-magnesia or plant-ash glass

Group III is comprised of 16 vessels. Fifty samples of ***Group III*** from Kadhima, Mughaira and Shiqaya have similarities with the chemical composition of ***Group III*** glass from Unguja Ukuu. As has already been mentioned in subchapter 6.3 (for more information see subchapter 6.3), in terms of its chemical composition ***Group III*** , common in Unguja Ukuu, Kadhima, Mughaira and Shiqaya, is typically characterised by distinctly different levels of soda and silica and by exceptionally high aluminium and lime concentrations. Glass showing this characteristic elemental feature is in stark contrast to all other glasses. In comparison with ***Group III*** glasses from the Kuwaiti sites (the evidence from the chemical analysis shows that sometime late in the 7th century AD the specific plant ash compositional group came into widespread use in Kadhima, Mughaira and Shiqaya in the Persian Gulf), ***Group III*** from Unguja Ukuu was not at all the most dominant group. However, for the purposes of this study, which is primarily concerned with the discovery of a new group in Iraq, particularly in Baṣra, this group is still of great importance. It is especially notable that the specific group represents a rare new plant ash compositional type and matches with two samples: sample 1260, excavated in a small tell containing large quantities of molten glass refuse in Tel Umm Jirin, Iraq, and sample 5341, excavated in Hamadan, Iran.

For further examination, Unguja Ukuu samples were compared with samples from Egypt, Levant and Iraq. ***Figures 6.6.3.1-6.6.3.3*** show the comparison of the Unguja Ukuu samples with samples from the above places. A careful glance through the figures shows a significantly large compositional distinction between ***Group III*** glasses and those from Egypt, Levant and Iraq. An exception is fragment 1260 from Tell Umm Jirin, Iraq. A further point must also be made here. ***Group III*** comprises only one closed and semi-open flaring straight vessel, in contrast with the eleven, uncovered at the Kuwaiti sites, alongside one closed and semi-open folded and flattened vessel, in contrast with ten uncovered at the Kuwaiti sites. The open types are represented by only two triangular-beaked rims, two open plain fine vessels and one thick open plain vessel. Additionally, there were two flat and one push-up base, a foot droplet and three trail decorated fragments.

Table 6.18. Group III glasses resemble glasses from an unknown source.

Sample	Type	Group	Type/form	Resemblance
GL 3257a	Plant-ash	Group III	Trail decorated	unknown source
GL 3257b	Plant-ash	Group III	Trail decorated	unknown source
GL 3306	Plant-ash	Group III	Trail decorated	unknown source
GL 2478	Plant-ash	Group III	Open triangular beaked rim	unknown source
GL 2981	Plant-ash	Group III	Open triangular beaked rim	unknown source
GL 2580	Plant-ash	Group III	Open plain thick	unknown source
GL 2403	Plant-ash	Group III	Open-plain fine	unknown source
GL 2522	Plant-ash	Group III	Open-plain fine	unknown source
GL 2475	Plant-ash	Group III	Closed flaring straight	unknown source
GL 2978	Plant-ash	Group III	Closed and semi-open folded and flattened rim	unknown source
GL 0984a	Plant-ash	Group III	Flat base	unknown source
GL 0984b	Plant-ash	Group III	Flat base	unknown source
GL 657	Plant-ash	Group III	Push-up base	unknown source
GL 2455	Plant-ash	Group III	Foot droplet	unknown source

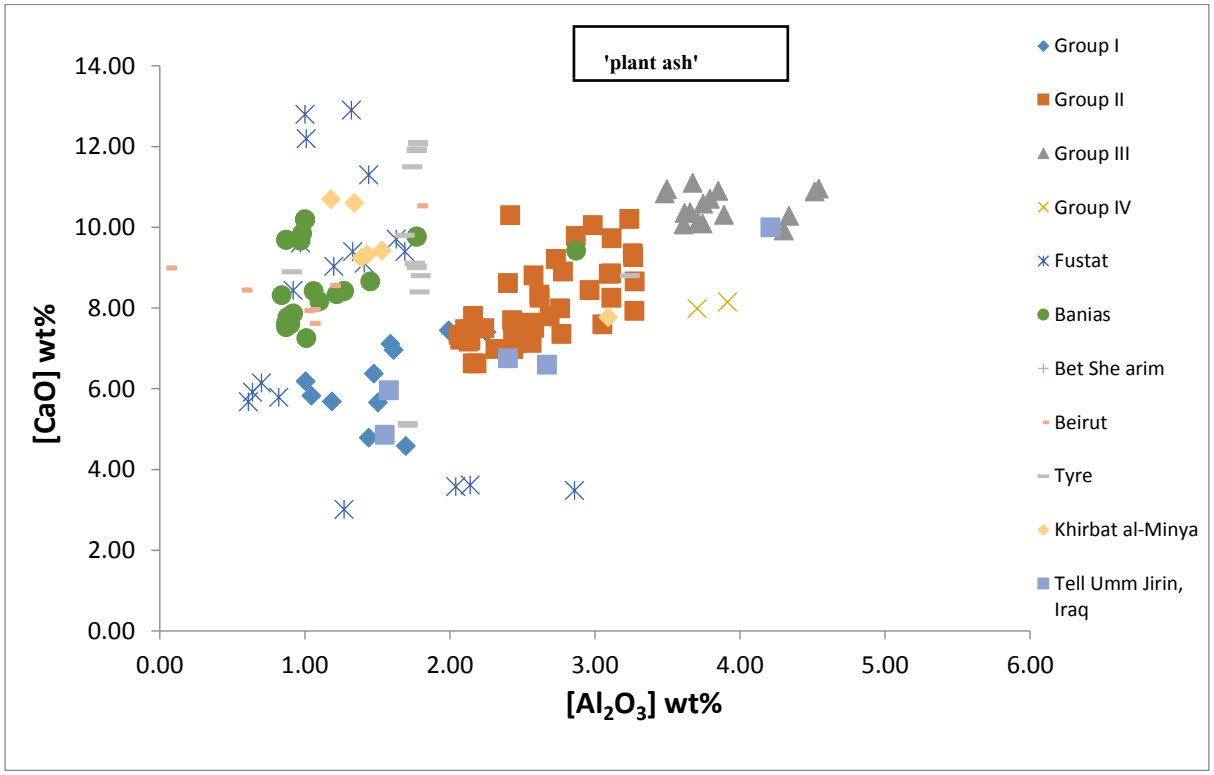


Figure 6.6.3.1*: Plot of aluminium versus lime for all analyzed plant ash glasses from Unguja Ukuu and archaeological sites from Egypt, Levant and Iraq.*

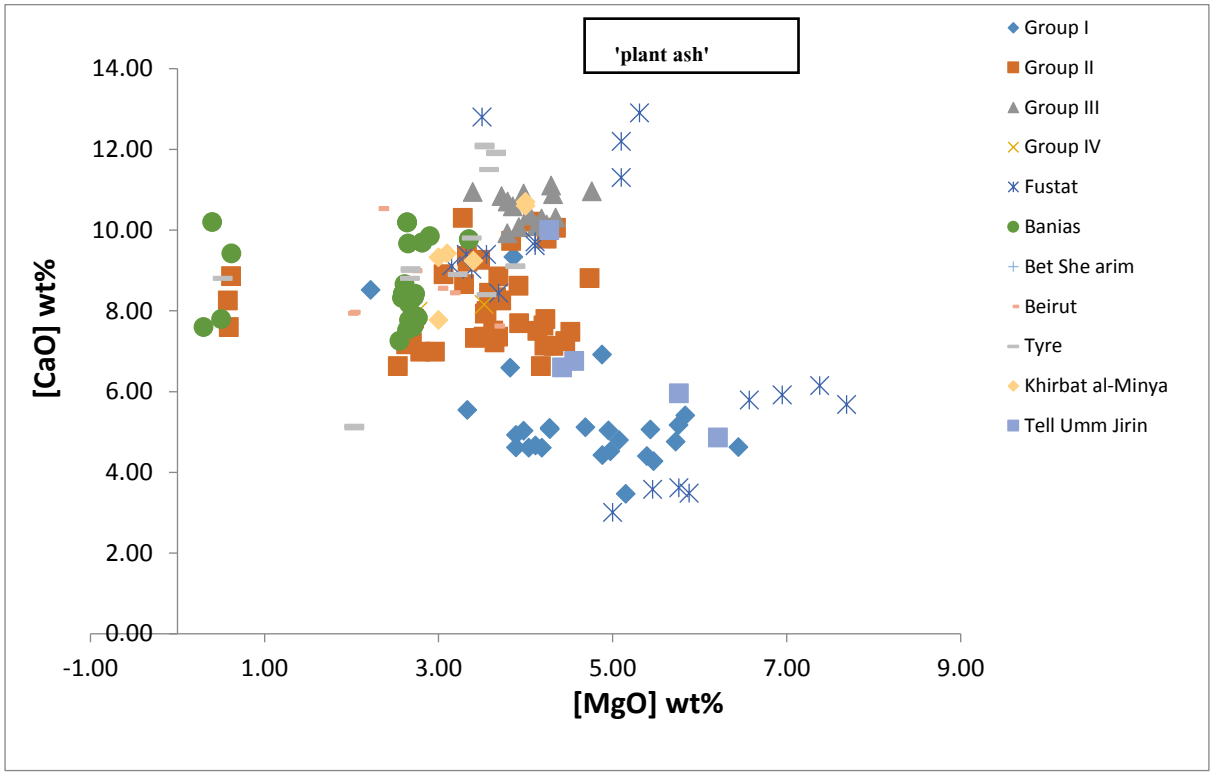


Figure 6.6.3.2: *Plot of magnesium versus lime for all analyzed plant ash glasses from Unguja Ukuu and archaeological sites from Egypt, Levant and Iraq.*

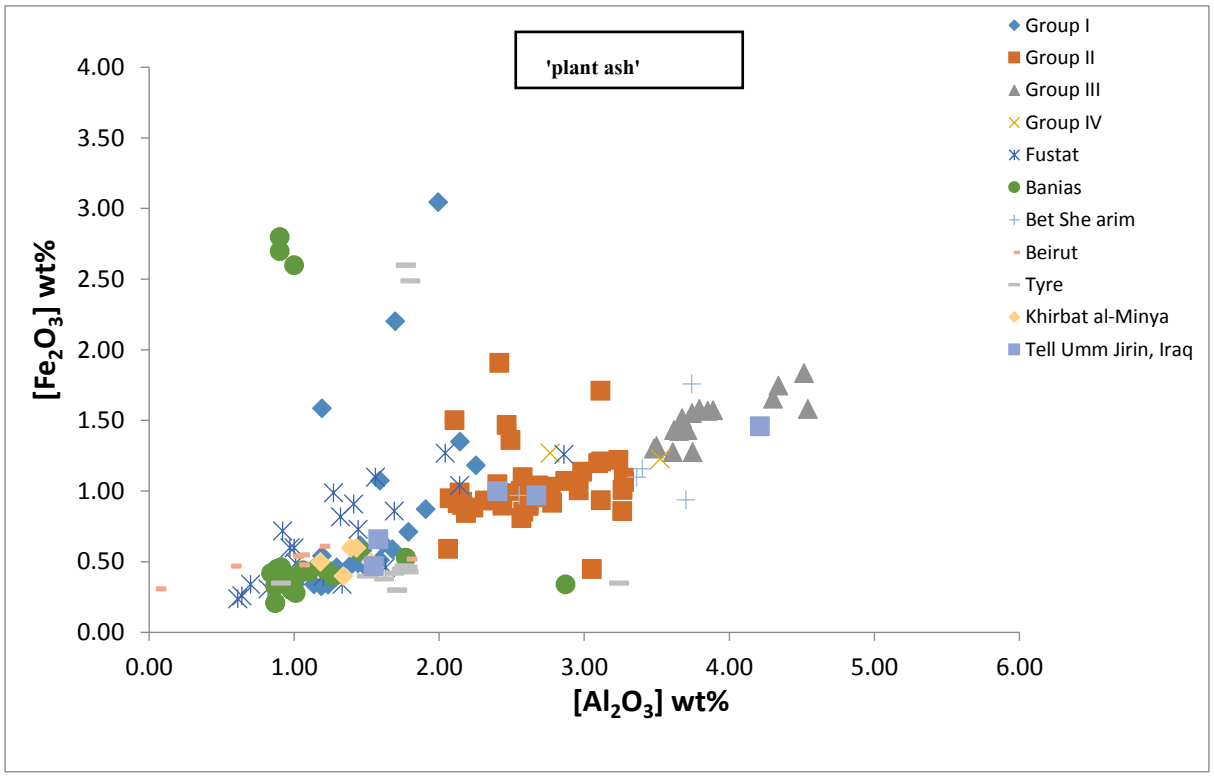


Figure 6.6.3.3: *Plot of aluminium versus iron for all analyzed plant ash glasses from Unguja Ukuu and archaeological sites from Egypt, Levant and Iraq.*

Three bi-plots for both 2 sets of oxides were created for major and minor element results. It is worth emphasizing that alumina, lime, magnesium and iron concentrations were chosen for the bi-plots. All of them consider being instructive for the thesis. The reason for comparing those major and minor elements was because previous studies suggest broad geographical provenance based on alumina, lime, magnesium and iron concentrations for early Islamic plant-ash glasses (Henderson *et al.*2016:138). ***Figure 6.6.3.1*** is a bi-plot of weight % alumina versus weight % lime. It can be seen that the overall values of alumina of ***Group III*** samples are between 3.50 to 4.50% which are about two times greater than the alumina values of Fusṭāṭ , Banias, Bet Shearim, Beirut, Tyre and Khirbat al-Minya glasses. Fragment 1260 from Tell Umm Jirin, Iraq is a very close match with ***Group III*** samples having high alumina and lime values and probably came from the same source. Up to this point the interpretation of the figures has been straightforward but for ***Group III*** samples that is not quite the case having the higher alumina values than any of the other early Islamic plant-ash glasses reported here. The alumina values of ***Group III*** samples are so different from Egyptian and Levantine glasses just discussed. The reason for the high alumina values of ***Group III*** samples as opposed to other glasses is not known at this time but it will be discussed later in the next chapter.

In ***Figure 6.6.3.2***, ***Group III*** samples contain greater magnesium and less lime than the majority of the Tyre glasses and greater magnesium and lime than Banias and Beirut glasses. Furthermore, there is no correlation between ***Group III*** samples and Fusṭāṭ glasses. It can be observed that Fusṭāṭ glasses are distinctly different having either higher or lower calcium oxide. The lime values of Fusṭāṭ glasses are also different from ***Group III*** samples. Fusṭāṭ glasses are clearly distinctive from ***Group III*** samples either having higher than 10% lime either having lower than 10% lime. Fragment 1260 from Tell Umm Jirin, Iraq continues to be a very close match with ***Group III*** samples having around 4% magnesium and around 10% lime. In ***Figure 6.6.3.3,*** all ***Group III*** samples plot with the highest alumina contents having higher more than 3.50% alumina and more than 1.30% iron concentrations than Egyptian and Levantine glasses. This is an observable separation between ***Group III*** samples and Egyptian and Levantine glasses and a clear similarity with fragment 1260 from Tell Umm Jirin, Iraq. The differences in alumina, lime, magnesium and iron concentrations between ***Group III*** samples and Egyptian and Levantine glasses, in any event implies that ***Group III*** samples were produced separately at different workshops or different sites.

6.6.4 Group IV high-magnesia or plant-ash glass

We now come to what is designated as ***Group IV*** in this study, comprising 2 vessels (**Table 6.19**). The group is characterised by an alumina content between 3.70 to 3.92%and lime of about 8%. The soda is typically in the range of 14%, and silica is typically 61%. The group bears close similarities to a group from the Kuwaiti sites that presents homogeneity in the composition of glass, suggesting a relatively stable and fixed recipe based on silica fluxed with plant ash. By comparing all the groups with sites in Levant, Syria and Egypt, there are no matching samples. The group bears close resemblance to Tell Zujaj, but it is distinguishable. Even closer are twenty-eight samples from the Kuwaiti sites and three samples uncovered at Nishapur. A comparison of the ***Group IV*** glass with glass from the Kuwaiti sites, Tell Zujaj, Nishapur and neighbouring regions follow below (***Figures 6.6.4.1-6.6.4.3***). One exception is vessel 5340 from the area around Nishapur, known as Hamadan, which seems to overlap with ***Group IV*** glass.

*Table 6.19. **Group IV** glasses resemble glasses from an unknown source.*

Sample	Type	Group	Type/form	Resemblance
GL 3255	Plant-ash	Group IV	Closed flaring straight	unknown source
GL 2100	Plant-ash	Group IV	Closed neck and shoulder	unknown source

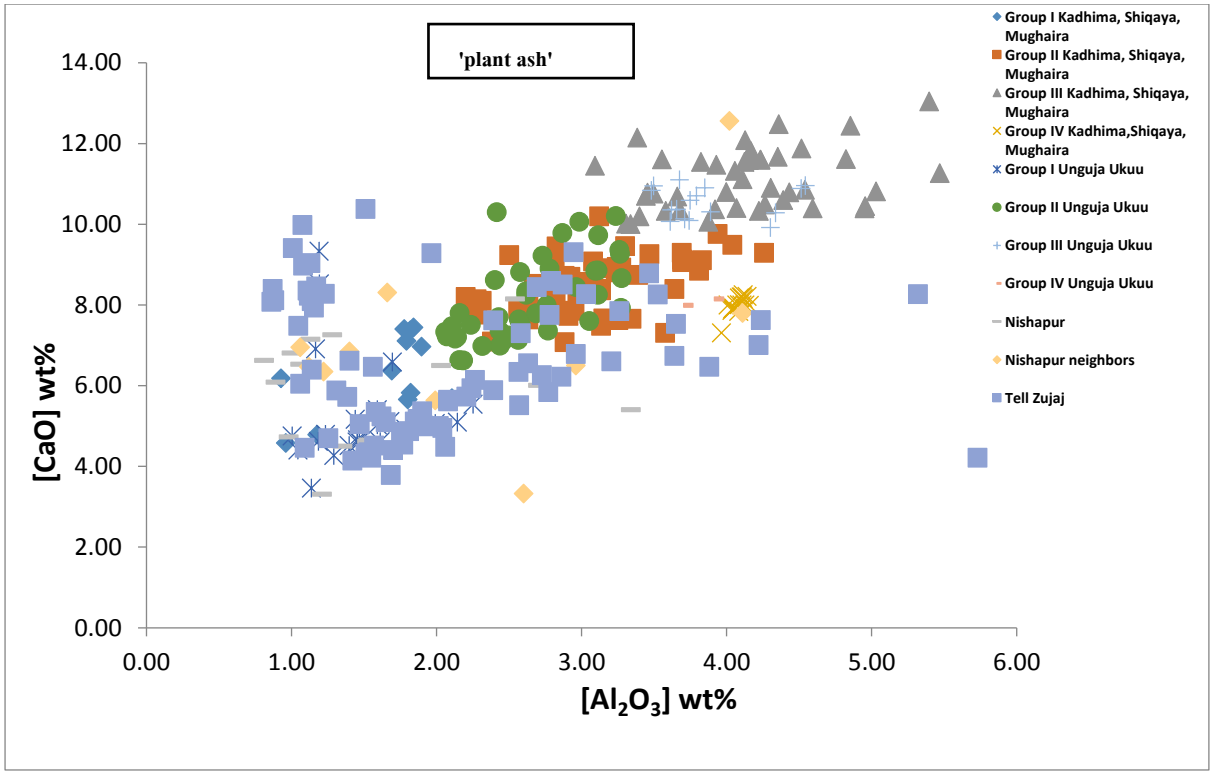


Figure 6.6.4.1*: Plot of aluminium versus lime for all analyzed plant ash glasses from Unguja Ukuu and archaeological sites from Nishapur, Nishapur neighbors, Tell Zujaj and Kuwaiti sites.*

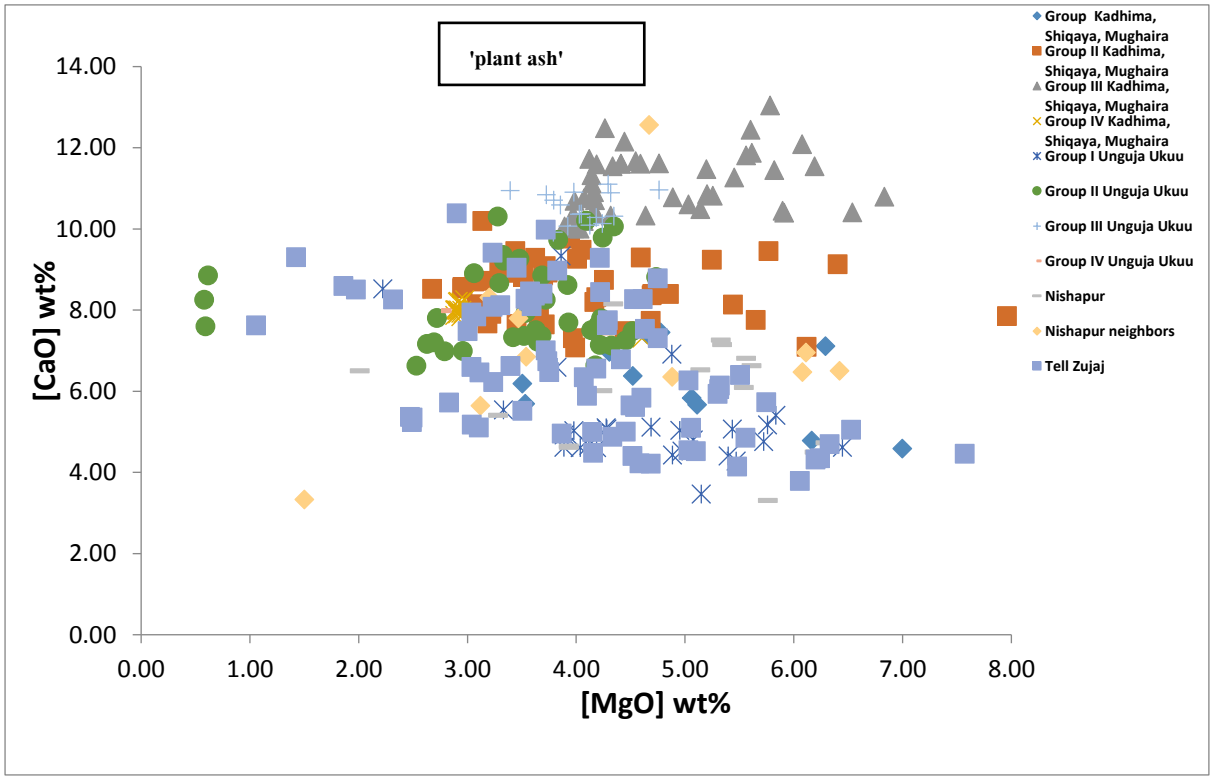


Figure 6.6.4.2*: Plot of magnesium versus lime for all analyzed plant ash glasses from Unguja Ukuu and archaeological sites from Nishapur, Nishapur neighbors, Tell Zujaj and Kuwaiti sites.*

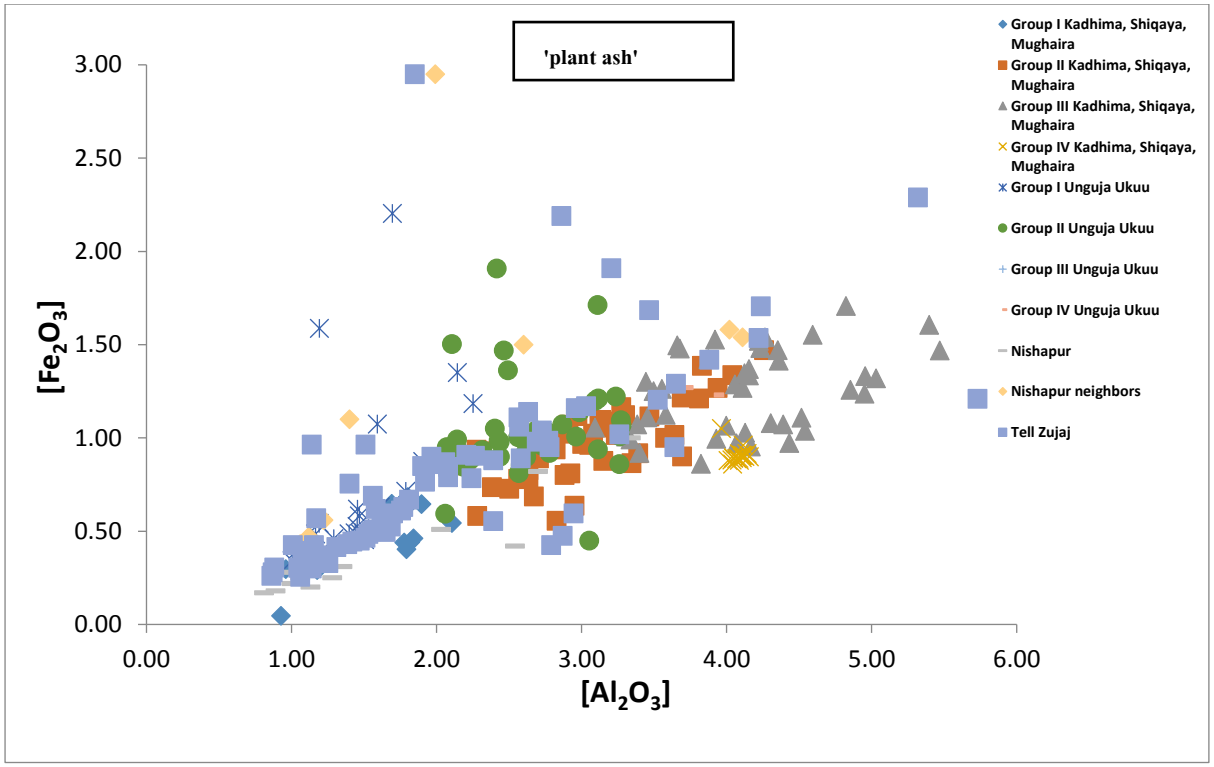


Figure 6.6.4.3*: Plot of aluminium versus iron for all analyzed plant ash glasses from Unguja Ukuu and archaeological sites from Nishapur, Nishapur neighbors, Tell Zujaj and Kuwaiti site.*

In ***Figure 6.6.4.1***, scatter plot of alumina versus lime shows a strong correlation between ***Group IV*** samples from Unguja Ukuu having alumina around 3.80% and lime around 8% with ***Group IV*** samples from the Kuwaiti sites having alumina around 4% and lime around 8%. ***Group IV*** samples from Unguja Ukuu are distinctly different from Tell Zujaj glasses having higher alumina more than 3%. The mean values of CaO and Al_2O_3 in ***Group IV*** samples are closest to vessel 5340 from the area around Nishapur, known as Hamadan. In ***Figure 6.6.4.2***, ***Group IV*** samples from Unguja Ukuu correlate to ***Group IV*** samples from the Kuwaiti sites in terms of concentration of magnesium and lime. ***Group IV*** samples from Unguja Ukuu differs from the majority of Tell Zujaj glasses having lower than 4% magnesium. It can be seen that ***Group IV*** samples from Unguja Ukuu contain low levels of magnesium, of the order of 2.76-3.52% while Nishapur and neighbouring regions glasses contain high levels of magnesium greater than 3%. Although differences in magnesium and lime concentrations between ***Group IV*** samples from Unguja Ukuu and Nishapur and neighbouring regions glasses observed in ***Figure 6.6.4.3*** a good match found with vessel 5340 from the area around Nishapur.

Concentrations of iron and aluminium in ***Group IV*** samples from Unguja Ukuu are high, up to

1.27 and 3.92 respectively. In ***Figure 6.6.4.3,*** it can be seen that these values are higher than Nishapur and the majority of Tell Zujaj glasses. ***Group IV*** samples from Unguja Ukuu slightly differs from ***Group IV*** samples from the Kuwaiti sites having a higher iron concentration greater than 1%. The differences of the ***Group IV*** samples from Unguja Ukuu and Tell Zujaj, Nishapur and neighbouring regions glasses could suggest that ***Group IV*** samples were made in a different location.

6.6.5 Summary of Unguja Ukuu results

An investigation of low-magnesia and high-magnesia glass uncovered at Unguja Ukuu was presented here. According to chemical analysis results, the majority of the samples were plant-ash soda glass. This type of glass was divided into four subtypes with different alumina and lime concentrations (here designated as ***Group I***, ***Group II***, ***Group III*** and ***Group IV***). This division suggests different origins. As already stated at the Kadhima, Mughaira and Shiqaya results, ***Group I*** glasses are chemically similar to Iran/Iraq glass coming from Ctesiphon, Sāmarrā, Sīrāf, Nishapur and the surrounding area, **Group II** is similar to glass from northern Syria (al-Raqqa), while in contrast ***Group III*** and ***Group IV*** do not resemble glass found at any known contemporary early Islamic sites. The mineral-soda glasses from Unguja Ukuu were divided into three subtypes (here designated as ***Group 1***, ***Group 2*** and ***Group 3***), coming from three different silica sources.

6.7 Comparison samples from Kadhima, Mughaira and Shiqaya with samples from Unguja Ukuu

At its core, this study, which focuses on glass from the Persian Gulf and the East African coast, was not only about the discovery of common glass groups that could provide evidence of trade/exchange relationships between the Persian Gulf ports of Baṣra or Sīrāf with the East African coast, but also how we could use glass to examine trade/exchange relationships between those places, Andrew Blair, using typological analysis, was able to show trade/exchange relationships between the two places through the presence of eight types of 'closed and semi-open' vessels, found at Kadhima, Shiqaya, Mughaira and Unguja Ukuu (Blair,2016:342). Furthermore, eight types of open vessels with a distinct rim were also found at both places (Blair, 2016:342). The overall picture, based on this remarkable degree of overlap, led Blair to suggest that it was likely the glass began its journey to East Africa in the Persian Gulf ports (Blair, 2016:342). This is supported by the fact that the Persian Gulf was considered to be the main outlet for ´Abbāsid -inspired activity in the West Indian Ocean at this time (Blair,2016:342). This subchapter will compare glasses from Kadhima, Mughaira and Shiqaya with glasses from Unguja Ukuu to verify Blair's assumption. The most important contribution of the current research, of course, comes from the results of the electron microprobe analysis. For those who are interested primarily in discovering trade/exchange relationships between the above places, chemical analysis shows the existence of common glass groups at both places, especially ***Group III*** which is rare across the entire Islamic world. But if these chemical analysis results are to make meaningful contributions to our understanding of the history of trade, and to become something more than just information, they cannot be studied in isolation.

At some point, one must venture beyond to another level, that of a comparison of the glasses from the Kuwaiti sites with those from Unguja Ukuu. Strictly speaking, this comparison poses several risks and many difficulties, especially in the interpretation. First, it must be kept in mind that the discovery of common groups is not enough to prove trade or exchange relationships between the ports. Early Islamic glasses, particularly of the finer quality, produced at the major production centres (Northern Syria, the Eastern Mediterranean, Egypt, Iraq and Iran), were extensively distributed across a wide area through a complex network of exchange. Part of the challenge in the analysis is to compare the glasses and look for appropriate evidence that could prove glass exchange or trade between the Persian Gulf ports and the East African coast.

Secondly, regarding the origins of the vessels themselves, it must be realised that just because the glassware travelled from Baṣra (in close proximity to Kadhima, Mughaira and Shiqaya) or Sīrāf does not necessarily mean they were made there. In fact, most of the glasses, especially the finer sorts, were of types that were well known from finds in other areas and could have been imported from major production centres. A second objective of the research is to discover the origins of the Kuwaiti and Unguja Ukuu glasses and to compare whether the glass was coming from the same sources. Moreover, the comparison will reveal the trade/exchange relations of the above places alongside with other places in the Islamic world and other markets. We cannot assume that all the glassware was made in one specific area. It is expected that glass from more than one major production centre will be identified. It is unlikely that the traders restricted themselves to the trade of glass from one major centre.

In *Figures 6.7.1-6.7.3*, by comparing plant-ash glass from three Kuwaiti sites with plant-ash glass from Unguja Ukuu, it can be seen that glass from four different geographic areas arrived in the Persian Gulf and the East African coast. If we accept that each of the four compositional groups correspond to different geographical areas (this can be said with certainty for ***Group I*** and ***Group II*** but not for the others), then it can be observed that the majority of the glasses from both places belong to ***Group II***; the specific group is related to northern Syria, perhaps al-Raqqa. Firstly, it was observed that a scratch decorated vessel (GL2244), three closed flaring straight necks, a lug handle (GL0717), an angular base (GL0757) and a closed neck and shoulder (GL572) from Unguja Ukuu overlap with the ***Group II*** glass from Kadhima, Mughaira and Shiqaya, which was related to northern Syria and consists mainly of closed ribbed necks, open-stepped rims and closed flaring straight necks. Secondly, a large number of vessels at both places belong to ***Group I***, and these vessels likely originate from Iraq (Sāmarrā or Ctesiphon). Finally, there are glasses from ***Group III*** and a small quantity from ***Group IV*** related to unknown sources. The absence of plant-ash glasses from Baghdad, Takht-i Sulaiman, Banias, Tyre, Bet She'arim, Beirut, Khirbat al-Minya is remarkable. Generally speaking, glass coming from northern Syria, Sāmarrā or Ctesiphon was expected to be found.

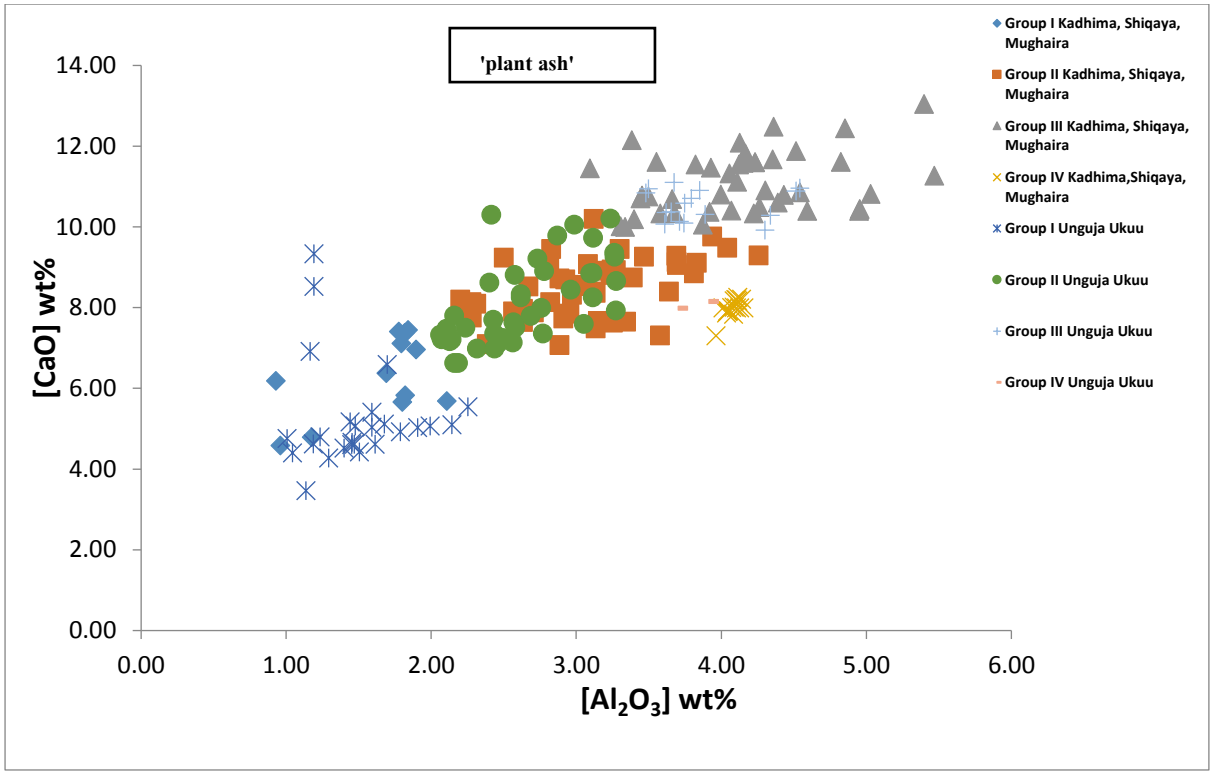


Figure 6.7.1*: Plot of aluminium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and Unguja Ukuu, Zanzibar.*

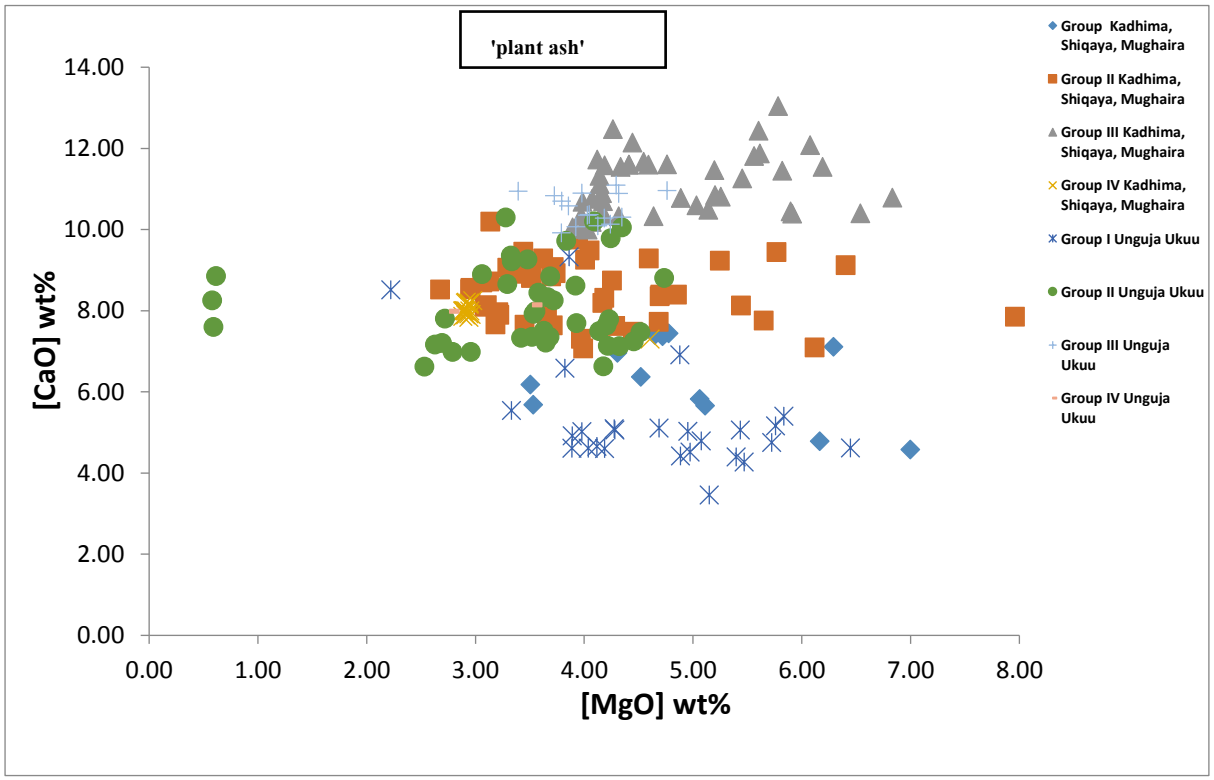


Figure 6.7.2*: Plot of magnesium versus lime for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and Unguja Ukuu, Zanzibar.*

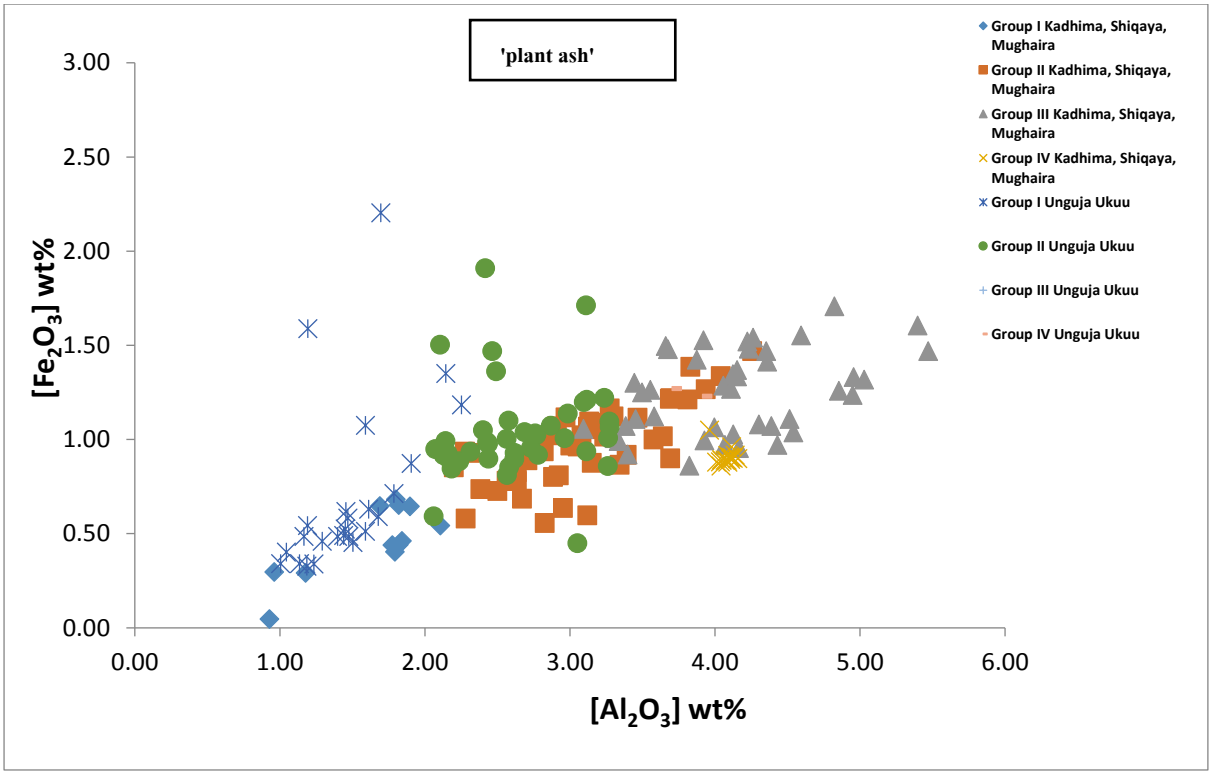


Figure 6.7.3*: Plot of aluminium versus iron for all analyzed plant ash glasses from Kadhima, Mughaira, Shiqaya and Unguja Ukuu, Zanzibar.*

An important contribution made by this research is the demonstration that across all the Iranian/Iraqi glasses, the glasses tended to originate from Sāmarrā and Ctesiphon. When the samples related to Iranian/Iraqi glasses were examined, it was observed that vessels uncovered at Unguja Ukuu, namely a scratch decorated vessel (GL2846), a vessel with a vertical wide neck (GL1337), a closed neck and shoulder (GL0904) and a pushed-up base (GL77), bear similarities to four closed ribbed necks (GL879, GL923, GL692, GL1264) and an open plain fine vessel (GL1003) from Kadhima, Mughaira and Shiqaya. All the samples above have similarities to the green wheel cut facetted glasses produced and fused at Ctesiphon (Henderson *et al.*,2016:142). Moreover, a wide neck (GL0143) and a ring base vessel (GL1044) from Unguja Ukuu bear resemblances to an open stepped rim from the north Persian Gulf coast (GL1329) and three vessels uncovered in Ctesiphon. Observing ***Figures 6.6.1.1-6.6.1.6*** and **Table 6.16**, part from Ctesiphon, Sāmarrā, which is 84 miles away from Ctesiphon, was the main source for the Unguja Ukuu vessels. The following vessels bear similarities to a closed-plain vertical neck vessel (GL 85) from Kadhima and an open inward folded rim vessel (GL1848) from Shiqaya, related to glass produced and fused in Sāmarrā: eight plain-rounded rim vessels (GL1853, GL0889, GL

119, GL1618, GL2723, GL0079, GL1030, GL1747), a scratch-engraved vessel (GL0090), a pinched vessel (GL0470), a rolled in rim vessel (GL2616), a closed flaring rolled in vessel (GL 3198), two ribbed-narrow necked vessels (GL1638, GL0949), two ring based vessels (GL1046, GL1044), a wide neck vessel (GL0143), a thick open plain vessel (GL2980), an open inward-folded rim vessel (GL0190), a trail decorated sample and a lug handle from Unguja Ukuu.

6.7.1 Iraqi and Iranian glasses

In ***Figures 6.7.1.-6.7.3***, the majority of the Kuwaiti glasses that belong to **Group I** are represented by plots at the side of the graph, and ***Figures 6.3.1.1- 6.3.1.3*** showed that these plots were green wheel-cut facetted glasses that were made and fused in Ctesiphon (Henderson *et al.*,2016:142). In contrast, the majority of Unguja Ukuu glasses that belong to **Group I** are represented by plots at the side of the graph, and ***Figures 6.6.1.1-6.6.1.6*** showed that these samples were made and fused in Sāmarrā (Henderson *et al.*,2016:142). An important question thus arises. Why was there a preference in Unguja Ukuu for glasses produced in Sāmarrā, of all the Iraqi/Iranian glasses? Of course, there is a possibility that the available evidence is limited by the random selection of the samples. But there is also a possibility that the evidence points to the ´Abbāsid capital, Sāmarrā, together with northern Syria, as the most important markets for Unguja Ukuu. While chemical compositions reveal the origin of early Islamic glass at both places, it was not possible to establish trade relation because there is only weak evidence. The existence of the same types of glass coming from the same sources is not definitive proof that the glass began its journey to Unguja Ukuu from the north Persian Gulf or from the main port for Iraq on the Gulf, Baṣra. There were several routes that the glass could have followed.

Baṣra, founded in the early years of the Islamic conquest, was not the only major port. Sīrāf was an international entrepot in the Persian Gulf, but it prospered later than Baṣra, in around the mid-9th century AD (Mason, Kealle,1991:53). Chronologically speaking, it is more likely then that the glass started its journey from Baṣra, which was characterised as a 'bride of the sea' connecting the Gulf region to the Indian Ocean (Potter,2009:4). Başra was located far up an inland river, the Shatt al-Arab, 72 miles upstream from the sea. From the mouth of the river, scratched decorated, open-stepped rims and closed flaring wide vessels from northern Syria

could be sent to Sīrāf or Muscat for further transport. Finding evidence for this, however, is difficult with the above chemical analysis alone. It seems that we can know next to nothing about the trade activity between the two sites. But this is actually not the case, as current chemical analysis provides the most reliable information about the trade between the two sites.

Chemical analysis reveals the existence of a rare type of glass in large amounts in Unguja Ukuu and in Kadhima Mughaira and Shiqaya. This type of glass includes all the vessels belonging to **Group III**; across the entire Islamic world, it can be found in a sample at Tel Umm Jirin, Iraq and in the above places. We now possess strong evidence of the glass trading activities and the maritime glass trade network between Baṣra port and Unguja Ukuu. It would be helpful in the future if the characteristic dark green vessels uncovered across the early Islamic world and related to the Sasanian/Islamic sites in Iraq were chemically analysed, or if trace or isotope analysis were conducted. This would be an interesting proposal for future researchers.

6.7.2 Open types of vessels

According to the typological analysis conducted by Andrew Blair, the early Islamic glass collected from the Persian Gulf sites and Unguja Ukuu along the East African coast seems to have a rather limited repertoire of vessel forms and rim types. After chemical analysis, it was possibly to identify with certainty which raw materials were used for the fusion of the vessels. A surprising and original finding of this research was the demonstration that in northern Syria, perhaps in al-Raqqa, in the Iraq/Iran area (Sāmarrā and Ctesiphon) and at an unknown place, there must have been an atelier/ateliers specialised in the fusion of specific open and closed or semi-open vessel forms. *Table 6.20* was created in an attempt to pinpoint the potential specialisation. Seven open types and four closed or semi-open types common to both places are listed here, and their compositional group and origin combined together. **Table 6.20** shows that the stepped rims, the most distinctive type from the early Islamic glass tradition, are well represented at both sites. We now have quantitative and qualitative evidence that all the analysed samples from Unguja Ukuu originate only from northern Syria, perhaps al-Raqqa, while there is considerable variation in the origins of the Kuwaiti samples (the majority come from northern Syria, of course, but also from the unknown source and from Ctesiphon). We might, therefore, assume that northern Syria's

workshops were specialised in the fusion of open stepped rims. This may seem like weak evidence. Nonetheless, if we assume that the stepped rims uncovered at Unguja Ukuu bear similarities to the scratched decorated vessels that originated from specialized workshops in northern Syria, then it is not difficult to imagine that the open vessels with stepped rims travelled together with the scratched decorated vessels from northern Syria.

It appears from chemical analysis results that another type of early Islamic glass that could have travelled together with the above glasses was a glass of the triangular-beaked rim variety. But this was not unexpected. Andrew Blair was of the opinion that the triangular-beaked rims share a 'chaîne opératoire' with the stepped rims, suggesting a similar geographic origin (Blair,2016:87). Part of the challenge in the analysis was to check whether rims share a common origin at both places and whether they come from the same geographic area as the stepped rims. Before proceeding to chemical analysis results, it must be mentioned that although the same proportion of 'triangular-beaked' rims were found at the Kuwaiti sites and Unguja Ukuu, only one sample from Unguja Ukuu was analysed. The chemical analysis conducted on this sample provided an answer to the question of whether the 'triangular-beaked' rims came from the same area as the stepped rims; the results proved that northern Syria was the place where the glass started its journey, and probably the vessels themselves. If we take into consideration the high level of standardization of those rims, it seems quite reasonable to assume that in northern Syria, perhaps in al-Raqqa, there existed a highly localised glass production centre where craftsmen had the knowledge to create 'triangular-beaked' rims (Blair,2016:315). The number of 'triangular-beaked' rims at the Kuwaiti sites and Unguja Ukuu demonstrate that this specific type of vessel was extremely popular and widespread.

Another popular and widespread vessel type found at both places was that of the inward-folded rims. A small number of these rim types were made in northern Syria and Sāmarrā. But attention has to be drawn to the majority of those vessels uncovered at the Kuwaiti sites, which were made of glass from an unknown source. The large number of samples from this unknown source suggests that there was a place where perhaps the Mesopotamian glassworkers had adequate knowledge of a procedure that led to a thickened, rounded and slightly inverted rim. But identifying the exact location of this place is currently impossible. While it remains uncertain what created this specific Kuwaiti interest in inward folded rims, one can hardly fail to note their popularity throughout the Persian Gulf and their wide distribution. Meyer observed that inward folded rims without ridges or with moulded decoration can be seen in the 7th-8th century AD deposits at Nippur (Blair,2016:99). But whether the inward folded rims came from the unknown source, or from northern Syria or Sāmarrā, is impossible to know.

Table 6.20 Common types at Kadhima, Mughaira and Shiqaya and Unguja Ukuu.

Type/Form	Kadhima/Shiqaya/ Mughaira	Resemblance	Unguja Ukuu	Resemblance
	Number/Group	Place	Number/Group	Place
Open-stepped rim	3 Group I 5 Group II 6 Group III	Ctesiphon al -Raqqa unknown source	9 Group II	al-Raqqa
Open-triangular beaked rim	10 Group II	al-Raqqa	1 Group II	al-Raqqa
Open-inward folded rim	1 Group I 4 Group II 14 Group III	Sāmarrā al-Raqqa unknown source	1 Group II	al-Raqqa
Open-plain rounded rim	1 Group III	unknown source	8 Group I 1 Group II	Sāmarrā al-Raqqa
Open-plain fine	1 Group I 3 Group II 1 Group III	Ctesiphon al-Raqqa unknown source	1 Group II 3 Group III	al-Raqqa unknown source
Open-flared sided	1 Group I	al-Raqqa	1 Group II	al-Raqqa
Open-rolled in rim	2 Group III	unknown source	1 Group I	Sāmarrā
Closed ribbed neck	4 Group I 2 Group III 3 Group III	Ctesiphon al-Raqqa unknown source	2 Group I 1 Group II	Sāmarrā al-Raqqa
Closed & semi-open flaring straight	1 Group I 1 Group I 12 Group II 11 Group III	Ctesiphon Nishapur al-Raqqa unknown source	2 Group II	al-Raqqa
Closed & semi-open closed and flattened rim	4 Group II 8 Group III 1 Group IV	al-Raqqa unknown source unknown source	2 Group II	al-Raqqa
Closed and semi-open flaring-rolled in rim	5 Group II 1 Group III	al-Raqqa unknown source	1 Group I	Sāmarrā

The most common type of glassware at Unguja Ukuu was the glassware with plain rims (rounded), exclusively found in a distinctive 'ice-blue' glass. This type was identified in Kuwait in just a single fragment. In general, owing to the high level of standardization the Sāmarrā's glassworkers using 'ice-blue' glass specialised in the fusion of relatively plain, slightly thickened and rounded rims, with the pinched technique of tooling the predominant decoration. It was interesting to check whether the single fragment (GL1363) from Kuwait also came from Sāmarrā.

While it was expected that the 'ice blue' fragment would have come from Sāmarrā, it actually turned out to have originated from the unknown source. We can, therefore, make the following conclusion: that in the atelier/ateliers at Sāmarrā and the unknown place, there was a preference to work plain rims (rounded) only from 'ice-blue' glass. It is impossible to say with certainty whether workshops outside of Sāmarrā imitated the high standards of the decoration, especially with tooling plain rims (rounded), or whether craftsmen from Sāmarrā were moved to that unknown place to produce the 'ice-blue' glass or the plain rims (rounded). In an attempt to reconstruct the trade between Unguja Ukuu and the Kuwaiti sites, new questions such as these arise which would be interesting for future research to explore.

6.7.3 Closed or semi-open types of vessels

Now we turn to the closed or semi-open types. Through chemical analysis results, we are now in a position to draw the conclusion that northern Syria was a great market for the flaring straight necks found at the Kuwaiti sites. Northern Syria was also the place that the two unique samples uncovered at Unguja Ukuu came from. It seems that in northern Syria, perhaps in al-Raqqa, and in the unknown place, there were craftsmen familiarized with the creation of vessel necks that splay gently outwards from the body towards the rim (Blair,2016:74). Apparently, the flaring neck (straights) were not as popular in Unguja Ukuu as in Kadhima, Shiqaya and Mughaira. So, we can speculate as to why this type was found in Unguja Ukuu. Considerable emphasis must be placed here on transport mechanisms; by ship, there are limits to what can be transported. Vessels with flaring necks were more difficult to transport across long distances due to their fragility. These considerations are also valid for another common type of vessel found in both places: vessels with folded and flattened rims.

The folded rims that were normally flattened by marvering were shown in the quantitative and qualitative results to have come from the Kuwaiti sites and Unguja Ukuu in northern Syria. It is noteworthy that at the Kuwaiti sites, the folded and flattened rims also originated from two other unknown places. Finally, we must comment on the ribbed necked vessels uncovered at both places, that are dated to the 8th-9th century AD. By observing *Table 6.20*, it can be seen that even though this type was generally quite standardized, it originated from different places. So,

'ice-blue' ribbed necks started their journey to Unguja Ukuu from Sāmarrā and northern Syria, while the colourless ribbed necks at the Kuwaiti sites came from Ctesiphon, an unknown source and northern Syria. According to Andrew Blair, the vessels themselves do not appear particularly precious, but they could have been used to transport or store a precious commodity, such as perfume oils, powdered medicines or exotic ground spices (Blair,2016:70). As was mentioned at the start of this subsection, some types of vessels were encountered only in one place and not the other. Those are listed in *Table 6.21.* This means that glass from specific places appreciated in vastly different ways between Kuwait and Unguja Ukuu (Blair,2016:345). The non-common type is an indication that although a unity existed in the Persian Gulf and that east African coast there was a limit to the unity (Blair,2016:345).

As far as we are concerned, it must be noted that only two types of decorated vessels, trailed and dimpled, were encountered at both places; of course, this was to be expected as little early Islamic glass was actually decorated (Blair,2016:319). One point must be made here, which is that trailed or dimpled samples from Kadhima, Shiqaya and Mughaira were not selected for analysis. The decorated vessels from Unguja Ukuu and their origins are shown in *Table 6.22.* Before closing this subchapter, it must be emphasised that this method of comparing the glassware from two distant geographic areas proved very helpful in identifying that there were specific types of open, closed and semi-open vessels that were related to specific production places, from which they were traded and were very popular and widespread. The comparison also turned out to be helpful in showing specific trade/exchange relations between northern Syria and the Kuwaiti sites and Unguja Ukuu. It also illuminated the special relationship between Unguja Ukuu and Sāmarrā, and the special connections between the Kuwaiti sites and Ctesiphon and an unknown place, probably in Iraq. All these considerations, however, suggest complex trade or exchange relations between the Persian Gulf and the East African coast.

Table 6.21 *Non-common types at Kadhima, Mughaira and Shiqaya and Unguja Ukuu.*

Type/Form	Kadhima/Shiqaya/Mughaira		Unguja Ukuu	
	Number/Group	Resemblance Place	Number/Group	Resemblance Place
Open plate			3 Group III	al-Raqqa
Open-rolled in rim	4 Group II	unknown source		
Open-plain thick			1 Group I	Sāmarrā
			1 Group III	unknown source
Closed plain vertical	4 Group I	Ctesiphon		
Closed flaring wide			1 Group II	al-Raqqa
Closed neck and shoulder			2 Group II	al-Raqqa
Wide neck			1 Group I	Sāmarrā
			1 Group I	Siraf
Vertical neck wide			1 Group II	al-Raqqa
Lug handle			1 Group II	al-Raqqa
Ring base			2 Group I	Sāmarrā
			1 Group II	al-Raqqa
Push-up base			5 Group II	al-Raqqa
ABC vessel	16 Group IV	unknown source		
Miniature jar			1 Group II	al-Raqqa

Table 6.22 *Decorative types at Kadhima, Mughaira and Shiqaya and Unguja Ukuu.*

Type/Form	Kadhima/Shiqaya/Mughaira		Unguja Ukuu	
	Number/Group	Resemblance Place	Number/Group	Resemblance Place
Scratch-engraved			1 Group I	Sāmarrā
			2 Group II	al-Raqqa
Pinched			1 Group I	Sāmarrā
Trail decorated			2 Group I	close to
			1 Group I	Sāmarrā
			1 Group II	Ctesiphon
				al-Raqqa
Cane mosaic			1 Group II	al-Raqqa

6.8 Comparison samples from Kadhima, Mughaira, Shiqaya, Unguja Ukuu with samples from Sīrāf

At its core, this study, which focuses on glass from the Persian Gulf and the East African coast, is not only about the discovery of common glass groups that could provide evidence of trade/exchange relationships between the Persian Gulf ports of Baṣra or Sīrāf with the East African coast, but also how we could use glass to examine trade/exchange relationships between those places. Blair was of the opinion that the early Islamic glass uncovered at Unguja Ukuu had probably begun its journey from the major commercial ports of the Persian Gulf, Başra and Sīrāf (Blair,2016). Through typological analysis, Blair observed a number of similarities between glasses uncovered at Kadhima, Shiqaya, Mughaira, Unguja Ukuu and Sīrāf (***Figure 6.8.1.***, Blair,2016:20). Blair suggested, based on this remarkable degree of overlap, that it was likely that the glass began its journey to East Africa in the Persian Gulf ports (Blair,2016:342). This is supported by the fact that the Persian Gulf was considered to be the main outlet for ´Abbāsid - inspired activity in the West Indian Ocean at this time (Blair,2016:342). Sīrāf especially was a major commercial port from the early medieval era, 800-1050 AD, with close trade relations with Başra, the Indian Ocean and the East African coast (Whitehouse,1970:141,Swan *et al.*,2017:102). The main objective of this subchapter is to examine the glass trade between Kadhima, Mughaira, Shiqaya, Unguja Ukuu and Sīrāf to verify Blair's assumption.

We know next to nothing about glass trade activity between the north Persian Gulf coast, Sīrāf and Unguja Ukuu. But chemical analysis can help in the reconstruction of trade between Sīrāf, the Kuwaiti sites and Unguja Ukuu. For that purpose, glasses from Sīrāf will be compared with the glasses from the Kuwaiti sites and with those from Unguja Ukuu. ***Figures 6.8.2-6.8.4*** show this comparison. Strictly speaking, in this comparison, as already mentioned in subchapter 6.5, there are risks and difficulties involved in the interpretation. First, it must be kept in mind that the discovery of common groups is not enough to prove trade or exchange relationships between the ports. Early Islamic glasses, particularly of the finer quality, produced at the major production centres (Northern Syria, the Eastern Mediterranean, Egypt, Iraq and Iran), were extensively distributed across a wide area through a complex network of exchange. Part of the challenge in the analysis is to compare the glasses and to look for appropriate evidence that could reveal glass exchange or trade between the Persian Gulf ports and the East African coast. Secondly, regarding



Figure 6.8.1: *Kadhima, Mughaira and* Sīrāf *on the Persian Gulf (created by Andrew Blair) (Blair,2016:20).*

the origins of the vessels themselves, it must be realised that just because the glassware travelled from Baṣra (in close proximity to Kadhima, Mughaira and Shiqaya) or Sīrāf does not necessarily mean they were made there. In fact, most of the glasses, especially the finer sorts, were of types that were well known from finds in other areas and could have been imported from major production centres. If the glass was traded from Sīrāf, it is almost certain that there will be common sources of the glass. Swan *et al.* (Swan *et al.*,2017) devoted a whole paper to a range of compositions of glasses present at Sīrāf to improve our understanding of whether the glass was produced there or imported from other places.

Figure 6.8.2. reveals that Main Group 1 and Main Group II glasses from Sīrāf differs from Kadhima, Mughaira, Shiqaya and Unguja Ukuu glasses. The alumina level in the Main Group 1 and Main Group II glasses from Sīrāf is noticeably lower, less than >2%, than in the Mughaira, Shiqaya and Unguja Ukuu glasses. The lime levels of the Main Group 1 and Main Group II from Sīrāf are about the same with ***Group II*** from Kadhima, Mughaira, Shiqaya and Unguja Ukuu glasses. As with the other groups from Sīrāf, one can determine that plot close to ***Group I*** from Kadhima, Mughaira, Shiqaya and Unguja Ukuu. The similarities could suggest a common source or location. Even though exact matches were not found Sīrāf low Zr, low Mn and high Al

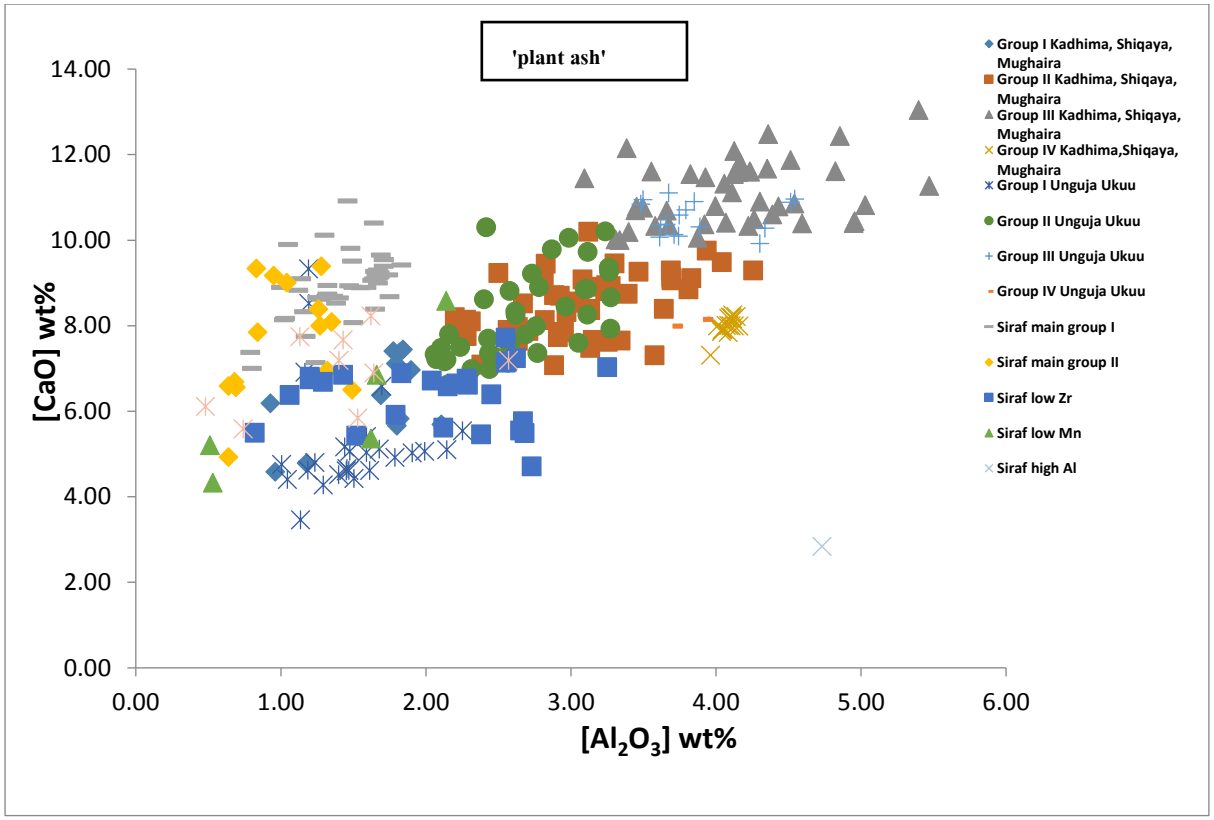


Figure 6.8.2: *Plot of aluminium versus lime for all analyzed plant ash glasses from Sīrāf with Kadhima, Mughaira, Shiqaya and Unguja Ukuu, Zanzibar.*

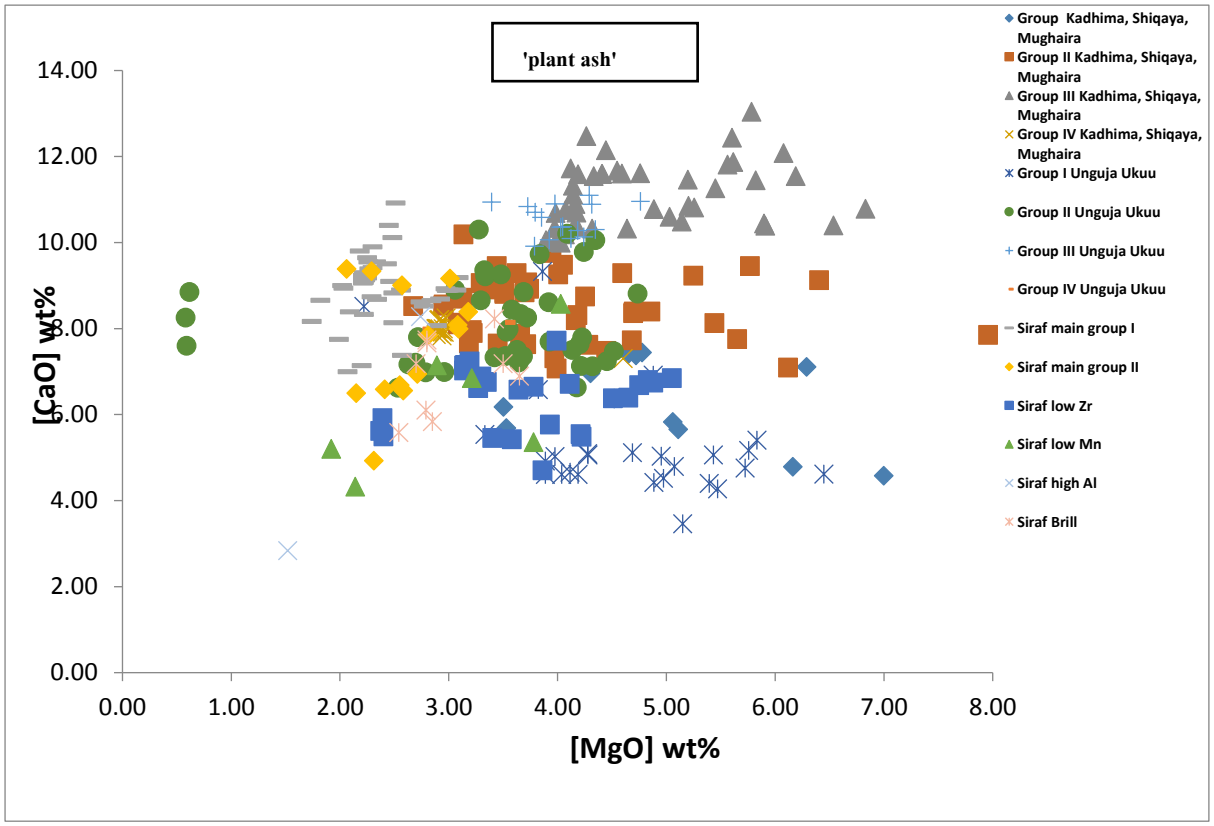


Figure 6.8.3: *Plot of magnesium versus lime for all analyzed plant ash glasses from Sīrāf with Kadhima, Mughaira, Shiqaya and Unguja Ukuu, Zanzibar.*

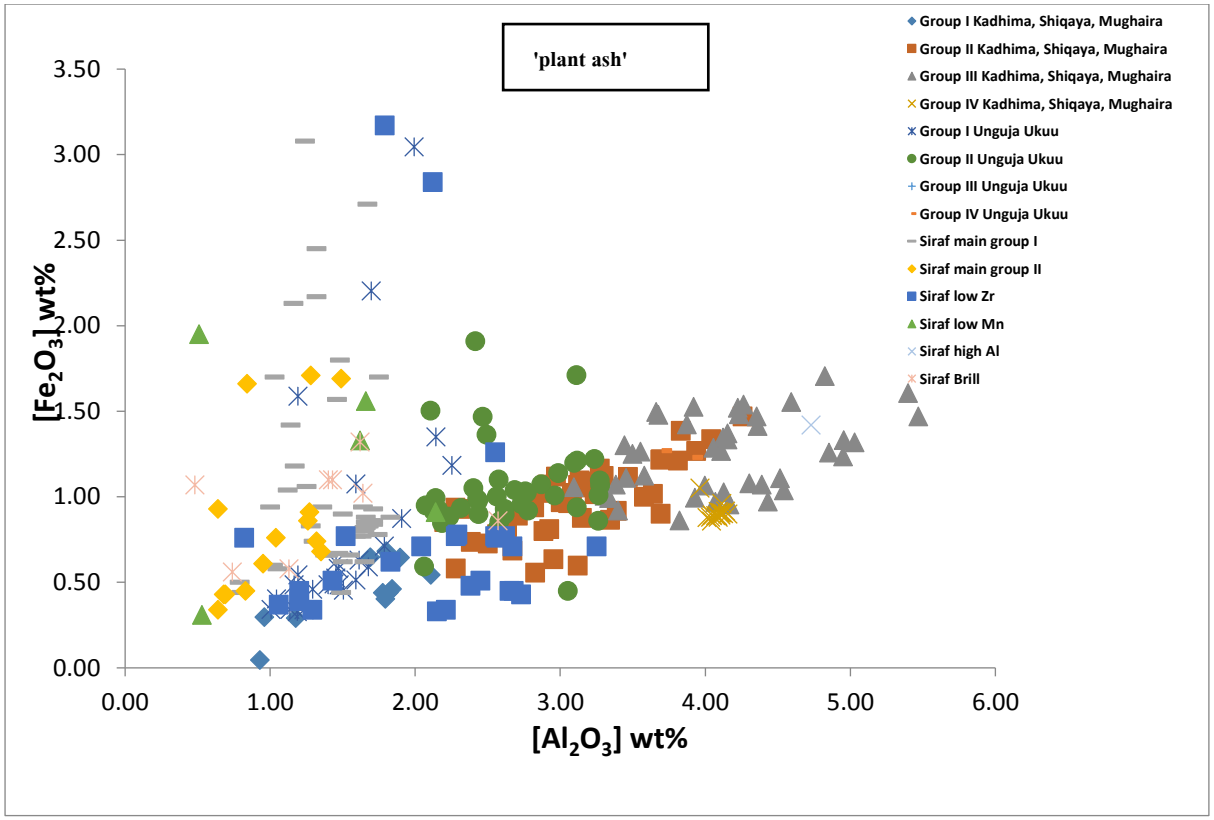


Figure 6.8.4: *Plot of aluminium versus iron for all analyzed plant ash glasses from Sīrāf with Kadhima, Mughaira, Shiqaya and Unguja Ukuu, Zanzibar.*

presumably, come from Iran and Iraq. In ***Figure 6.8.3,*** the magnesium ranges in the Main Group 1 and Main Group II glasses from Sīrāf are lower 2% than in Kadhima, Mughaira, Shiqaya and Unguja Ukuu glasses. Magnesium is elevated greater than 3% in the other groups from Sīrāf and the lime is lower than 8%; they could have been Iraqi or Iranian product. In ***Figure 6.8.4,*** the iron levels in Main Group 1 and Main Group II glasses from Sīrāf are higher and the alumina levels lower than in Kadhima, Mughaira, Shiqaya and Unguja Ukuu glasses.

When Swan chemically analysed the samples, he showed the existence of a potentially unique local glass produced in Sīrāf and a low Zirconium type of glass of 'East Persian' type, based on zirconium and chromium trace elements and alumina, lime and magnesia minor elements. There is a need to clarify whether local glass from Sīrāf was traded either to the north (Kadhima, Shiqaya and Mughaira) or to the south (Unguja Ukuu). Alternatively, the glasses might have travelled in reverse, reaching the north Persian Gulf coast from northern Syria and Iraq before being traded to Sīrāf and then to Unguja Ukuu. By comparing the Unguja Ukuu glasses with three Kuwaiti sites and Sīrāf, it can be seen that not all the compositional types uncovered at

Unguja Ukuu and the Kuwaiti sites have been identified in Sīrāf. The most interesting observation was the absence of the rare ***Group III*** glass in Sīrāf, as well as the widely distributed northern Syrian glass. Another interesting finding was the absence of the local glass produced in Sīrāf, either to the north or south. One exception is a vertical neck vessel (GL1337) unearthed at Unguja Ukuu that overlaps with the Main Group 1 from Sīrāf (***Figure 6.8.5***).

David Whitehouse (Whitehouse,1968) described the Main Group from Sīrāf; specifically, he notes that the vessels had thinly blown walls. They were either green in colour with a distinctive yellowish tint and bubbles, or blue in colour and bubble free (Whitehouse,1968;Swan *et al.*,2017:103). Most of them were undecorated and a few bear wheel-cut or mould blown patterns (Whitehouse,1968,Swan *et al.*,2017:103). The vertical neck vessel (GL1337) could be the only indirect indication of a possible glass trade between Sīrāf and Unguja Ukuu. But the existence of a unique sample is not evidence of participation in the glass trade system, as it could be an exchange product. The fact that Sīrāf 's local glass has not been found along the East African coast or even in closer proximity at the Kuwaiti sites could justify the conclusion that it was not an export product but was probably intended for daily use. Moreover, the inferior quality of the majority of the glass, along with the presence of bubbles, can support this interpretation. In fact, it is reasonable that this type of glass would be absent from other locations since during our period of interest this specific type of glass was even rare in Sīrāf. Whitehouse (Whitehouse, 1968) noted that it was rare before 825-850 AD to 977-1055 AD, and then become the dominant type (Swan *et al.*,2107:103). The key to the glass trade lies in the research of the 'East Persian' type of high-quality colourless or nearly colourless glass often adorned with wheel-cut or carved decoration uncovered in Sīrāf (Swan et al.,2107:103). Whitehouse observed the similarity of that type of glass, designated as 'Low Zirconium' glass, with glasses uncovered in Nishapur. By comparing it with Kadhima, Mughaira, Shiqaya and Unguja Ukuu glass, we can see how it compares to eastern glasses from Iraq, including Ctesiphon.

There are similarities between a colourless vessel and vessels with open-stepped rims, closed ribbed necks, two closed and semi-open flaring straight necks and an open plain fine vessel from the Kuwaiti sites, and most importantly green wheel-cut facetted glasses made and fused in Ctesiphon. Henderson and his colleagues used trace element analyses to provide evidence for the provenance of the green facetted vessels (Henderson *et al.*,2016:142). A dark blue low Zirconium glass (009) from Sīrāf is notable. As it can be seen, it overlaps with a closed ribbed neck (GL1264) from Kadhima lower in ***Figure 6.8.2.*** graph from the northern Syrian glass collection.



Figure 6.8.5: A vertical neck uncovered in Unguja Ukuu, Zanzibar coming from Sīrāf port (photo taken by the author).

Nevertheless, Swan and his colleagues note that due to the lower magnesia and potash, this sample more closely aligns with the Syria-Palestinian glass (Swan *et al.*,2017:112). According to the current chemical analysis results, it is possibly of Iraqi or Iranian origin rather than Syrio-Palestinian. In contrast, a dark blue vessel (89) and a colourless vessel (30) of low Zirconium type seem to originate from northern Syria, based on our graph. There are also four samples of the 'East Persian' type that match with glasses from Iraq and northern Syria and are close to the Unguja Ukuu glasses. Finally, in relation to the glass trade, the only find that could support a maritime trade were the Eastern type of glasses and the products from the greatest market in northern Syria which were absent in Sīrāf. Unfortunately, we cannot make suggestions about that absence, but it is interesting for future studies to explore.

CHAPTER 7

DISCUSSION

7.1 Discussion of Early Islamic vessels from Kadhima, Mughaira and Shiqaya

7.1.1 Natron glass

Through chemical analysis results, conclusions can be drawn with reasonable certainty about the source of the mineral-soda glasses uncovered at Kadhima and Mughaira. In fact, the natron glasses overlap between the ***Levantine I*** and ***Levantine II*** types but fit closer with the oxide profile for ***Levantine I*** glasses. For the moment, through previous excavations and chemical analyses, it has been proven that ***Levantine I*** glass was produced using coastal sands that contained the right concentrations of quartz and calcite so that they could be mixed with soda (probably from the Wadi-Natrun in Egypt) to produce a blue-green glass (Freestone *et al.*,2003;Freestone *et al.*, 2008). This type of glass found in Apollonia-Arsuf, located on the Mediterranean coast of Israel, was produced in large tank primary furnaces in batches of five to ten tons (Tal *et al.*,2004; Freestone *et al.*,2008:71). The glass was greenish or transparent blue and of high quality, with occasionally bubbles (Tal,Jackson-Tal,Freestone,2004:56;Freestone, Jackson-Tal, Tal,2008:68). The same greenish (light-green blue) and transparent ice blue colour is found in the high-quality vessels labelled GL1051 and GL1798, natron glasses from Kadhima and Mughaira respectively. Whatever the exact colour and quality of these glasses, chemical analysis results suggest that the vessels from the Persian Gulf could be made by raw products in those furnaces in Levant, but it is impossible to conclude if the vessels were fused in Apollonia-Arsuf in Sharon Plain in Israel.

The Sharon Plain in Israel has a dozen sites related to the secondary production of glass. ***Levantine I t***ype glass could have been fused there or outside of Levant, as the excavations at al-Raqqa show (Tal,Jackson-Tal,Freestone,2004:59). Based on the Unguja Ukuu results, we can speculate about this issue. One of the main objectives of this research was to compare glasses from the Persian Gulf sites and Unguja Ukuu on the East African coast in an attempt to establish the trade connections. The most important contribution of this research was, of course, the establishment of trade relations between the Persian Gulf and the East African coast. According to the compositional data, the trade connection was proven through the existence of the same types of glasses. The strongest evidence, perhaps, is in the presence of ***Group III*** in great quantities at both places. One should not overlook the fact that this specific group of glass was

only found at Kadhima, Mughaira and Shiqaya and in a fragment in Tell Umm Jirin in the Diyala River Plain in Iraq, across the entire Islamic world (Brill,2005:83).

For a number of years, it was thought that early Islamic glasses must have come to Unguja Ukuu from the Persian Gulf ports but there was no evidence. Blair's suggestion to search for the ports in the Persian Gulf from which the glass from Unguja Ukuu might have started its journey now seems to be relevant (Blair,2016:342). Fortunately, Blair, undertaking a difficult and time-consuming task, recognised the significance of the similarities between the commonplace wares scattered along the East African coast and the Persian Gulf. Among the early Islamic glasses listed above from Unguja Ukuu, a small amount of ***Levantine I*** type glasses have been found. There is no reason to think that this small number of vessels was not traded, together with the other early Islamic glasses from the Persian Gulf ports. Reiterating the main point of this discussion is that there is sufficient evidence to demonstrate that the specific ***Levantine I*** type glasses from Unguja Ukuu were produced, fused and worked in Sharon Plain, Israel. The majority of the vessels bear pinched and trailed decoration. Trace element analysis shows that the vessels with this type of decoration were a speciality of the Levant. More specifically, there existed a workshop or workshops specialised in the practice of the hot-working technique, using decorative trails or pads of glass applied to the hot surface of the vessel (Goldstein,2007:15;Henderson *et al.*,2016:142).

For the purposes of this investigation, it is greatly important that pinch and trail decorated vessels of the ***Levantine I*** type from Unguja Ukuu were worked in a Levantine workshop or workshops. In the first place, the vessels would have been fused and shaped in a secondary workshop/workshops along the Levantine coast which was not far away from the primary workshop that made the raw glass. Moreover, it must also be recognised that the pinched and trailed vessels themselves, and not the raw material, was traded from the Levantine coast as far as Unguja Ukuu, Zanzibar. From the Sharon Plain, those vessels could be exported to Başra or Sīrāf because they were located close to the general maritime trade route, connecting the Persian Gulf with the East African coast. The question readily arises whether ***Levantine I*** type glasses from Kadhima and Mughaira were also fused and worked at the Sharon Plain and then traded along the Persian Gulf as vessels. Unfortunately, we cannot gather any indication about the place of their fusion (the fragments bear no decoration related to specialised workshops). But if the high-quality blue ***Levantine I*** wares from Unguja Ukuu arrived from Baṣra or Sīrāf as products of export from the Levant, the same model could apply for the ***Levantine I*** type wares from Kadhima and Mughaira.

7.1.2 Plant-ash glass

Leaving aside natron type glasses uncovered in Kadhima and Mughaira, we now come to quantitative and qualitative chemical analysis results of the plant ash glasses. The first group, designated here as ***Group I***, consists of 12 vessels, plus an outlier having the lowest concentrations of alumina and lime. While we can recognise those concentrations as having an Iraqi/Iranian provenance, it is noteworthy that the majority of the samples (n=9) have similarities to Ctesiphon glasses; the other samples have more similarities with Sāmarrā and Nishapur. Nine vessels were clearly distinguishable from the others in that they had the highest concentration of lime and bear similarities to the green wheel-cut facetted glasses produced, fused and worked in Ctesiphon. These include three open-stepped rim vessels, four closed-ribbed necks, a closed and semi-open flaring straight vessel and a plain open fine vessel. Through trace element analyses conducted by Henderson and his colleagues, it was proven that those green wheel-cut facetted glasses were made and fused in Ctesiphon (Henderson *et al.*,2016:142). This result was extremely interesting, providing us with a clear indication of the source of glass of the two most typical types in the early Islamic tradition, the vessels with closed ribbed necks and open stepped rims. It is not hard to imagine Ctesiphon (scientifically proven as a place of production of raw glass) as a place where facet-cut vessels, vessels with closed-ribbed necks or with open-stepped rims could be worked. But to clarify, this analysis does not prove the existence of a secondary workshop (this requires archaeological evidence before it can be stated with certainty) but it does clearly show that the glass that produced these vessels (maybe even the vessels themselves) was traded and reached the Persian Gulf (Brill,1970:111).

The Iraqi/Iranian glasses in Kadhima, Mughaira and Shiqaya were not restricted only to glass produced in Ctesiphon. Sāmarrā, which is 84 miles away from Ctesiphon, was the site of production for the glass used for a closed-plain vertical vessel and an open vessel with inward folded rim. It is especially interesting that the samples are similar to the green cut vessels that were made in Sāmarrā (Henderson *et al.*,2016:142). This, of course, does not mean that the vessels were worked there. This is no more than a possibility, even though Sāmarrā was considered a great glassmaking and glassworking centre during the early Islamic period. Finally, we must consider the last sample of ***Group I***, a closed semi-open flaring straight vessel that could not have originated from any of the Iraqi sites. There is an obvious reason for that. If one compares the colourless glass with the Iranian site, the sample has lower aluminium and magnesium concentrations and higher silica than other Iraqi glasses and has similarities with the

colourless cut facetted vessels from Nishapur. Recent trace element analysis proves that the colourless glass was produced in Nishapur and probably the glassworkers were using that glass to create the cut facetted vessels (Henderson *et al.*,2016:142). At this point we identify an intriguing issue. Why can we not recognise among the Iraqi/Iranian glasses any vessels originating from a very close geographical location, that of Sīrāf? Sīrāf was one of the most important ports of the Persian Gulf with trade relations with Başra close to the Kuwaiti Bay. Chemical analyses conducted by Swan *et al.* (2017) show that two types of glass have been produced there. But why this glass was not exported to the Kuwaiti Bay is something that needs further examination. Could this be a matter of chance or an indication of a preference of the merchants? It seems that merchants tended to be selective over certain types of vessels coming from Iraqi/Iranian sites. There is no definitive answer to the above question at the moment.

Group II is related to northern Syria. Here we encountered the most distinctive and well recognised types of early Islamic glass (Blair,2016:87). A remarkable result of the chemical analysis was that the specific group seems to have a rather limited repertoire of types including several variants. Here, twelve flaring straight necks (with a variable angle at which the neck flares) and five flaring necks with rolled-in rims (with considerable variety in rim diameter) belong to ***Group II.*** In the same group we encounter the triangular beaked rims and the open-stepped rims, types that were thought to have shared a similar chronology and geographic origin (Blair, 2016:87). Thirteen triangular-beaked rims (with considerable variation in terms of the thickness of the beaked rim) were encountered here (Blair,2016:93). A typical feature of this group is that almost all of the fragments are mostly made with light green-blue glass (Blair,2016:94). The similarity of this group with al-Raqqa's Type II glass supports an assumption that in northern Syrian workshops, craftsmen, using locally produced light green-blue glass, had the knowledge or felt comfortable to produce rims that had been thickened on the exterior, flattened on top and internally-beaked, giving a distinctive triangular profile (Blair,2016:93). Light green-blue glass was the most frequently used colour in ***Group II***. Apparently, light green-blue glass was used by northern Syrian craftsmen to produce another distinctive and well-recognised type of Early Islamic glass, the stepped rim (Blair,2016:87).

In fact, one might well be tempted to argue that specialised workshops existed in northern Syria to produce these rims, which are characterised by the presence of a thickened ridge or 'step' running horizontally (Blair,2016:87). Whatever the value of the assumption offered here, this could raise additional problems, because chemical analysis alone is not sufficient to determine the workshop/workshops where the vessels were fused. But even though a good number of

unsolved problems remain until today, there is another piece of information contained in the chemical analysis results from Unguja Ukuu that could support our assumption. By comparing the ***Group II*** open-stepped and triangular-beaked rims with samples from Unguja Ukuu, it can be seen that the above vessels are similar to the decorated and two scratch engraved vessels considered to be products of a specialised Syrian production zone. Recent chemical analysis from scratch engraved glasses from the stupa of the Famen Temple in China (samples that have similarities with the Unguja Ukuu scratch decorated vessels and to ***Group II*** Kuwaiti glasses) show that the Syrian vessels themselves could have travelled a long distance (Henderson *et al.*, 2016:175). Considering this long-distance travel, it is not unreasonable to think that the Unguja Ukuu scratched vessels started their journey from the Syrian region. It is thus reasonable to think that the same model or pattern of trade could apply to the other vessels of ***Group II***.

The next issue to discuss is the presence of a great amount of flaring necks along the Persian Gulf coast; due to fragility they were unlikely to have been moved around much. Despite this, twelve closed flaring straight necks from northern Syria were uncovered along the Persian Gulf coast. All the flaring necks were relatively simple bottles, supporting the assumption that it was not the vessel but the contents that was traded. It can be assumed that the bottles with the flaring necks transported precious commodities, such as cosmetics, medicines, species and toiletries along the East African coast (Blair,2016:77). Before we procced to ***Group III***, some observations must be made. Syria appears to be one of the greatest markets for the Persian Gulf coast. Ctesiphon, as previously seen, was another great market. It has been shown that the open stepped rims were produced even closer than northern Syria, in Ctesiphon. Furthermore, open stepped rims and open triangular rims were also produced in an unknown (probably Iraqi) location. In this sense, one could assume closer trading relations with areas situated in an ideal geographical position. However, this was not the case as only a small amount of open stepped rims come from Ctesiphon and the unknown place. While it remains uncertain why there was this special interest and popularity in the open stepped and open triangular vessels from northern Syria, one can hardly fail to see that the merchants or the inhabitants were selective in choosing certain types of vessels from certain places. This result, which came from the chemical analysis, was noteworthy as it shows which types of vessels came as products of a highly localised production in specific places. This was supported by the high level of standardisation in rims. The high levels of standardisation support a scenario in which craftsmen, having knowledge of specific rim types, shared their expertise across decentralised ateliers or moved to other centres.

The chemical analysis has provided a detailed picture of the chemical composition of the

artefacts belonging to ***Group III***, a composition that has been identified as a distinctive glass group(***Figure 7.1.1 & Figure 7.1.2,***Kenet,al-Duwish,2013:5). Observing chemical analysis results, it was demonstrated that the group has elevated aluminium and lime contents, which are very different from those of Levantine, Syrian, Egyptian and Eastern Iraqi/Iranian glasses. Here, we will provide some indicators as to its possible origin; without trace element and isotope analyses it is impossible to be said where that glass was produced. Trace and isotope analyses of ***Group III*** is an interesting future proposal. Glass showing these characteristic elemental features has been identified in nineteen samples in Unguja Ukuu. It is especially interesting that if one relates the dark green colour of the ***Group III*** glasses with the dark green based vessel (with a pontil mark), 1260, from Tell Umm Jirin, Iraq, and the thick based vessel, 5341, from Hamadan, Iran, one will observe that the glasses share similar chemical compositions (**Table 7.1.**,Brill,2005:77). The small tell, Tell Umm Jirin, located 12 kilometers northeast of Tel Aqrab, was a site where great quantities of molten glass refuse were unearthed (Brill,2005:65). Not only dark green but also aqua, colourless or slightly purplish glass vessels and large chunks of a peculiar material (the material was frothy throughout, with several occluded green glass areas) were identified by Robert McCormick Adams (Adams,1965) cited in Brill (Brill,2005:71). Brill (Brill,2005:71) chemically analysed glassy areas of the peculiar material, showing that it resembles glass found at the site. Brill was of the opinion that the material was a remain of an ancient frit or of a partially reacted glass batch Based on the Sasanian ceramic ' fossil types', Adams (Adams,1965) dated the glasses from Tell Umm Jirin to between the 5th and 6th century AD. But recent excavations suggested that the glasses should be dated later than originally considered (Wells,2015:1). A question that arises is why ***Group III*** is similar to glass uncovered in a Sasanian or later period in Tel Umm Jirin (Khaled al-Bashaireh,2016:259). Either there is a problem with dating, or we can trace a continuity of the Sasanian tradition. But whether the origin of the ***Group III*** glass is Sasanian or Islamic, the most important issue in the current study. The chemical analysis that showed a high lime/alumina content in ***Group III*** has attracted considerable attention. We shall now try to discuss how alumina, lime and magnesium were incorporated into ***Group III*** glass. One characteristic of ***Group III*** glass is the high lime content.

The scholars Brill and Freestone, after careful chemical and isotope analyses, pointed out that lime was incorporated from sand, which contains intrinsic shell, and so the lime was not added to the batch deliberately by the glassmakers (such as by adding crushed shell or limestone to pure quartz sand) (Freestone,2006:12). Lime content is typically present at levels of 5%-10%, occasionally up to 10% or occasionally 12% (Freestone,2006:12). An outstandingly high lime

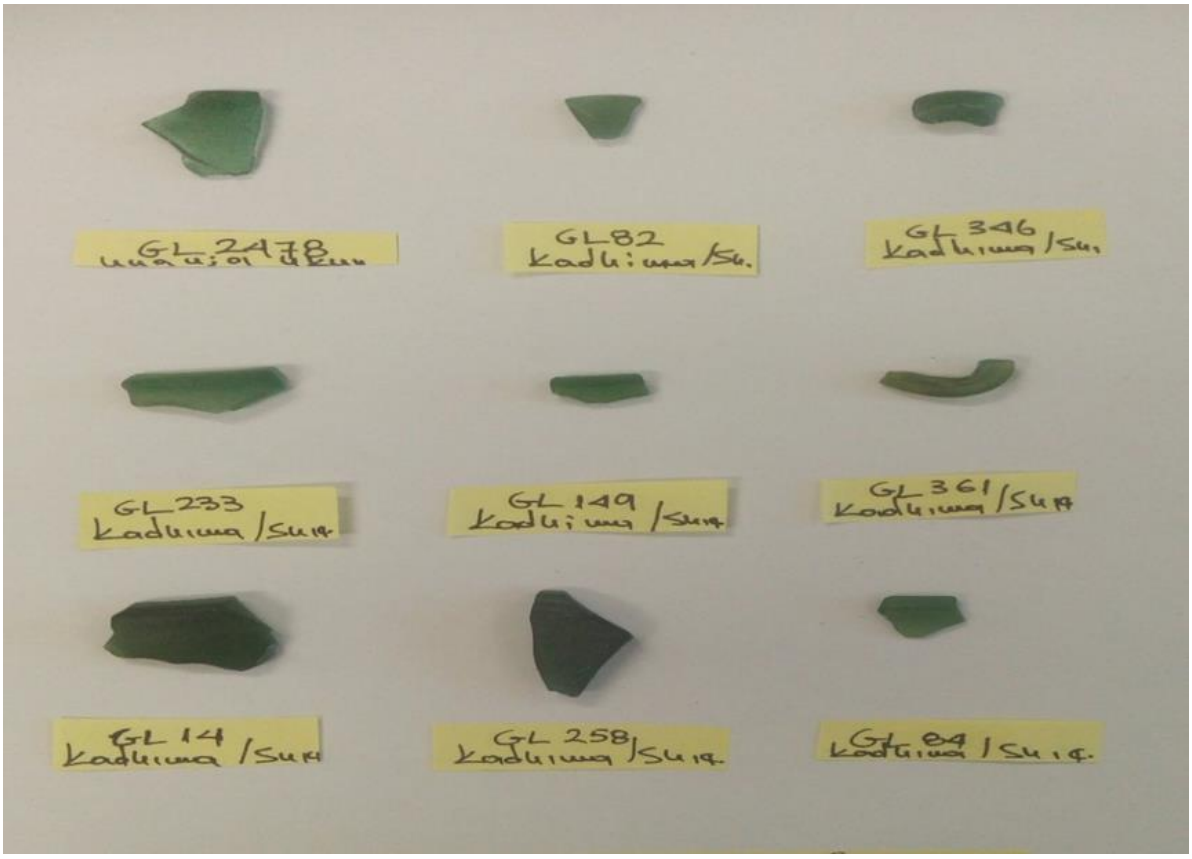


Figure 7.1.1*: Dark green glasses from Group III, found at Kadhima, Mughaira and Shiqaya (photo taken by the author).*



Figure 7.1.2*: Dark green glass from Group III (Kenet and al-Duwish,2013:5).*

content of more than 12% was present in the Bet She'arim slab, which has 15.9% CaO; the slab was produced by mixing two lime-rich materials: plant-ash and shell-bearing sand (Freestone, 1999:115). Another characteristic of the ***Group III*** glass is the high alumina content, which is in excess of 3% Al^2O^3. Freestone pointed out that alumina at a relatively high level was incorporated as a component of the sand (Freestone,1999:114). This suggests that the ***Group III*** glass used a high lime, high alumina silica source, such as quartz-rich sand or a quartz-rich sandstone or quartzite, but probably not pure naturally crushed silica pebbles. Freestone and his colleagues showed that the Levantine coastal sand and the sand in the Bay of Haifa had the appropriate concentration of lime to yield good, stable and workable glass.

Generally speaking, plant ash glass from the Levant has high calcium oxide levels of around 10%, as major, minor and trace element analysis conducted by Henderson and his colleagues show, but the Levantine plant ash glass differs from ***Group III*** in terms of the concentration of magnesium (around 2%) (Henderson *et al.*,2016:144). Higher concentrations of magnesium greater than 3.5% tend to occur in 7th century AD glasses from the East of the Euphrates in the region of the Persian Empire under the Parthians and the Sasanians (Freestone,2006:204, Simpson,2014:204). This appears to indicate a difference in raw materials and possibly in the species of plants that were ashed. It may be speculated that the glassmakers of the ***Group III*** glass were exploiting the desert plant or the Iraqi shrubs. From all the plant ashes that Brill (Brill,1999:208) has analysed, sample 1324, plant ash from a desert plant in Jezaziyat, Iraq, has the same aluminium ratio, around 4% (Tite *et al.*,2006:1287). All the other elements are lower; for example, plant ash from a desert plant in Jezaziyat has a lime concentration of 13%, while ***Group III*** glass has concentrations of around 10%-11% and magnesium 4%-6.8%, while the plant-ash in Jezaziyat around 8%. The assumption was that perhaps this was a reflection of the MgO-rich alluvium of the Euphrates and the Tigris (Freestone,2006:8). At this point, we cannot establish, nor is it essential to establish, whether the sand was obtained near the mouth of the Belus or another elsewhere. These sources could have provided coastal sand naturally containing calcium carbonate in the form of marine shell and limestone eroded from the cliffs, or river sand to which shell was deliberately added (Freestone,1999:114). This will be an interesting future proposal for research. It is not difficult to visualise glassmakers of ***Group III*** glass using a closer source of sand or a different species of plants (Freestone,1999:114). This interpretation is based on the presence of five commonly-occurring glass groups, based on the reflection of calcium carbonate and feldspar minerals in the sand, on the Levantine coast and further down the coast at Apollonia-Arsuf, Bet Eli,ezer, Hadera and in Egypt (Freestone,2006:12,20).

Table 7.1 Major element compositions of selected soda-lime-silica glasses.

Oxide	Kadhima/ a	Kadhima/ b	Tel Umm Jirin Hamadan	
Date	**mid-7 -8th C AD**	**mid-7th -8th C AD**	**5-6th AD**	**Islamic**
SiO_2	60.49	60.61	59.53	63.45
Al_2O_3	4.85	3.55	4.21	4.11
FeO	1.26	1.26	1.46	1.54
MnO	0	0	0.75	<
MgO	5.60	4.59	4.27	3.47
CaO	12.44	14.21	16.20	16.70
Na_2O	9.68	15.6	13.32	16.5
K_2O	2.75	2.45	2.75	2.41

Serious consideration needs to be paid to the dominance of the dark green colour in ***Group III*** glass. The majority of these glasses are notable for being green, perhaps indicating a dark sand on the coast. This implies high iron oxide contents in the sand, such that glassmakers would make a strongly coloured green glass (Freestone, 2006). It is particularly notable that the Fe_2O_3 levels were 1.11% to 1.70%, and this was probably added to ***Group III*** glass as a colourant. Rehren and his colleagues proved that the high concentrations of iron oxides are responsible for the green and dark green colours (Khaled al-Bashaireh, 2016:265). Iron was doubtless the oldest material that was specifically added as a constituent for colouring certain glasses (Turner, 1956:48). Whether additions of iron at such high levels would have effectively coloured ***Group III*** glass is unknown; this is only a probability. The Bet Shearim slab with high alumina/lime

concentrations have a similar greenish colour. In one essential respect, ***Group III*** differs from all the other major centres mentioned, so one is therefore forced to assume another great market for such a large amount of glass. Without trace and isotope analysis, we are limited in what we can say about the provenance of the group. It will be interesting in the future to check whether Başra in Iraq was the centre of the production of ***Group III*** glasses. Başra is a possible candidate in Iraq. During our period of interest, Baṣra was a major city in close proximity to the location of the ***Group III*** glass, a week's caravan journey away or two days by sea and river (Blair, 2016:341). Until now, glass from Baṣra has never been chemically analysed so there is a possibility that the green glass itself was actually produced and worked there. As such, it is possible that glassmakers there worked the open and closed and semi-open vessels of ***Group III*** glass.

Based on the chemical analysis results, we can say with certainty which specific types of vessels belong to ***Group III***. A remarkable result of the chemical analysis was that the group seems to have a rather limited repertoire of types, with several variants. Here, eleven flaring straight necks (with a variable angle at which the neck flares) and ten closed and semi-open folded and flattened rims were encountered. In fact, one might be tempted to conclude that they came from a specialised workshop/workshops, in an unknown place, perhaps Iraq, where glassworkers specialised in the production of light green-blue cylindrical necks with 'mushroom-shaped' or 'T-shaped' rims. These rims were achieved by folding the neck outward and then folding it a second time back over on itself, leaving a strong protruding flange (Blair, 2016:61). Although these vessels seem to be products of a specialised production, each fragment shows signs of irregularity or imperfection (Blair,2016:64). This type of vessel was one of the most distributed throughout the 7th-10th centuries AD. It is noteworthy that the glassworkers from this unknown location also specialised in the production of the light green-blue, colourless and olive-green necks that flare at a roughly constant angle (Blair,2016:75). The flaring necks (straight) could have been produced at this unknown location and used for storing or transporting precious commodities such as cosmetics, medicines, spices and toiletries to the Kuwaiti sites (Blair,2016:76). Several vessels of this type have been excavated in Nippur and are called 'Sasanian', but unfortunately have not been chemically analysed (Blair,2016:77).

An interesting result coming from the chemical analysis was that the open-inward and the open rolled in rims must have been produced at this unknown location. Straight to convex-sided open vessels (beakers or bowls) with rims that have been folded inward and downward were worked in that unknown place by craftsmen trying to join the rim with the internal vessel wall

(Blair,2016:98). Moreover, inward folded rims and also light-green blue rims with slightly turned-in mouths (through the process of rolling) seem to have been produced in the same place for a range of possible functions. While it remains quite uncertain what created this special interest in the open inward-folded rims and the closed folded and flattened rims at the Kuwaiti sites, it seems that the merchants or the inhabitants had a preference for these types of vessels coming from particular places. This result from the chemical analysis was noteworthy as again it shows which certain types of vessels were products of a highly localised production centre.

Finally, ***Group IV*** is characterised by a homogeneity of the samples, attributed to the fact that twenty-eight fragments belong to the most intact vessel found within the confines of the east room, in deposit (Blair,2016:179). With the exception of fragment 735, a closed ribbed neck, and fragment 1599, a closed and semi-open flattened rim, ***Group IV*** glass can be associated with a mostly intact open vessel with a plain fine rim, responsible for the large quantity of body and rim fragments. Once we recognise this, we can now search for the origin of the group. Twenty-eight shards clearly overlap with sample 5340 from Hamadan, a neighbouring region of Nishapur. The sample was an aqua vessel with decoration on a mould-blown dimpled body; the sample was dated later than the ***Group IV*** glass (late 7th to 8th century AD compared with the 10th or 11th century AD). As far as can be made out, this is not the only sample from the Persian Gulf coast that present similarities with samples from Hamadan. It seems possible that from a specific unknown glassmaking or glassblowing centre, specific types of vessels found their way to both Hamadan, Kadhima and Shiqaya. But it is impossible to say from the chemical analysis where exactly that location was.

It has been shown also that ***Group IV*** glass has similarities with, although is clearly distinct from, four samples from Tell Zujaj of Type 4 glass. This type of glass was fused there at Tell Zujaj. Finally, we must consider the two dark green transparent and one yellowish-green sample from Nishapur that have similarities to the Group IV glass. All three of these samples bear decoration: 3082 the alabastron bears facet-cutting, 5301 and 5302 bottles possess molded (Brill,2005:85). Also, two more samples (3255, a closed flaring straight vessel and 2293, a pushed-up base) uncovered in Unguja Ukuu, Zanzibar, have similarities. But we will come to the comparison of these samples with those from Unguja Ukuu in more detail in the following subchapter. Of particular interest here is the examination of the relation between all the above groups with glasses from Sīrāf and Unguja Ukuu, places with closed trade relations during our period of interest.

7.2 Discussion of Early Islamic glass from Unguja Ukuu

7.2.1 Natron glass

Through chemical analysis results, conclusions can be drawn with reasonable certainty about the source of the mineral-soda glasses uncovered at Unguja Ukuu. In fact, the investigation shows that the mineral-soda glasses and the natron glasses came from three different sources. More specifically, the cluster of the three glasses in ***Group 1***, two push-up bases and a ribbed neck, seems to be associated with ***Egyptian II*** glass. Egyptian II glass was identified by Foy *et al.* (Foy *et al.*,2003). The glass was made using a sand containing limestone, probably in inland Egypt, and seems to have been produced with a fixed recipe for consistent properties (Freestone *et al.*, 2000;Freestone,2003). The products of ***Egyptian II*** glass are dated to the 8th and 9th centuries CE and can be found at the secondary workshops in Fusṭāṭ (Shindo,2000), Tel Aviv (Freestone *et al.*,2015), and El-Ashmunein (Bimson,Freestone,1985), as well as at the market of Raya (Kato *et al.*,2009) and the monastery of Wadi al-Tur (Kato *et al.*,2009). Although the ***Egyptian II*** composition was better quality glass than the glass from the Levantine coast and was characterised by properties that a glassmaker would have preferred, which would have imparted a lower viscosity, and a lower melting temperature, only three samples with this compositional type were found (Freestone,2003). Taking into account that the raw glass of the ***Egyptian II*** glass had to be transported over a longer distance than the Levantine glass, this would have added significantly to its cost. It seems that for the glassworkers, the Levantine glass was cheaper to acquire as it was produced at a more proximal location (Freestone,2003). The ***Egyptian II*** glass has been found along with the glass from Unguja Ukuu and the ***Levantine I*** and the ***Levantine II*** glass. It seems that the glassmaking industry of the Levant and Egypt supplied natron glass to much of the world in late antiquity from Cyprus to Italy, and also to Africa. (Freestone *et al.*,2008).

The sixteen samples defined as ***Group 2*** seem to be associated with ***Levantine I*** glass (Freestone *et al.*,2000). This group is comprised of glasses with pinched decoration, applied bases, two lugs-handles, closed-flaring necks and plain-rounded rims. Freestone and colleagues originally identified and labelled the ***Levantine I*** group that comprises the 6th – 7th century AD glass from Dor and Apollonia (Freestone *et al.*,2000) and 4th century AD glass from Jalame (Brill,1988). Glass with ***Levantine I*** characteristics has also been excavated from early Islamic sites at al-Raqqa, Syria (Henderson,1995), as well as in the late Byzantine secondary workshop at Ramla (South), Israel (Tal *et al.*,2008), and the late byzantine secondary workshop at Beth Shean (Freestone *et*

al.,2000,Freestone et al.,2003). The analysis of Freestone and colleagues show that the glass from al-Raqqa had a very large compositional spread that probably reflects the large scale and date of glassworking in al-Raqqa (Freestone *et al.*,2008). The ***Levantine I*** group was produced using the renowned sand from the Belus Delta in the Bay of Haifa, or similar coastal sands that contain the right concentrations of quartz and calcite so that they could be mixed with soda (probably from the Wadi-Natrun in Egypt) to produce a blue- green glass (Freestone *et al.*,2003;Freestone *et al.*,2008). The sands seem to have contained more lime than the ***Levantine II*** glass and lower soda content (Freestone *et al.*,2008). This type of glass was produced in large tank primary furnaces of the type excavated at Apollonia-Arsuf in batches of five to ten tons (Freestone *et al.*, 2008). This type of glass is dated to between 7th and 8th centuries CE, dates that align with the pinched decoration of the Unguja Ukuu glass vessels. The pinched decoration is a typical decoration from the late Roman period (Shindo,2007).

Group 3, which consists of one plain-rounded rim and a pinched decorated fragment, overlaps with the ***Levantine II*** group that is associated with the large-scale manufacturing installations at Bet Eli'ezer, near Hadera in Israel. The ***Levantine II*** group is distinct from the Levantine I group in that it has lower lime and sodium and concurrently higher silica concentrations, indicating a different silica source but still some local coastal sand (Freestone, Gorin-Rosen,1999;Freestone *et al.*,2002a;2003;2008). The Bet Eli'ezer glass was used routinely to produce vessels in 6th – 7th century AD glassmaking, but the analysis of 8th century AD vessels from Ramla, from Raya, Tel Aviv, the monastery of Wadi al-Tur and now from Unguja Ukuu, show that the Bet Eli'ezer production extended into this period (Freestone *et al.*,2000;Freestone *et al.*,2002a,2003,2015;Kato *et al.*,2009). Freestone and colleagues observed a reduction in the sodium content to 12.1% in the Bet Eli'ezer glasses, suggesting a relative reduction in natron content of the batch to 20-25%, allowing the production of more glass for the same quantity of alkali (Freestone *et al.*,2000). The pinched decorated fragment has higher calcium contents that suggests it represents a contemporary Early Islamic production from another locality in the same region.

For further interpretation the majority of the studied samples from Unguja Ukuu that belong to the group referred here as ***Group 2***, the glass of this group was superimposing with those from all the sites of the ***Levantine I*** group. Through comparison of those samples with samples of the selected sites: Apollonia, Ramla, Dor, al-Raqqa and Jalame it was obvious that all the samples from Unguja Ukuu, except one pinched decorated fragment, overlap with the glasses from Ramla (South), and its compositions assemblages with vessels glass from the Apollonia and with chunks,

vessels and waste from Beth Shean. Freestone *et al.* (Freestone *et al.*,2008) has shown that Apollonia vessels of the Area M, with a limited compositional ranges, were a product of the single workshop with glasses of Ramla (South) and Bet Shean. The Unguja Ukuu assemblages with the vessels from Ramla (South) and Bet Shean, possibly show that samples from the site was the product of that single workshop. All the Ramla (South) glass, chunk glass samples and vessels, was contaminated with fuel ash and has eventually higher values of potassium (K_2O) above 1 wt% (Freestone *et al.*,2009). The contamination occurred possibly to the primary stage of manufacture in a single late Byzantine workshop because of some accident or peculiarity in the primary process (Freestone *et al.*,2009). The Unguja Ukuu vessels has lower values of potassium (K_2O) above 1 wt%, in which case means that are not contaminated and are not coming from the one-time accident of the melt. If the contaminated vessels from Ramla were the result of a general practice of that single workshop that means that the Unguja Ukuu vessels come from another locality in the same region.

This case study adds to the chemical analysis to draw archeological conclusions about the natron type glass imported to Unguja Ukuu. The analysis of vessels and the comparison with others found in different parts of the Islamic world yields useful information about the composition and provenance of the glass. It again shows that the Byzantine glassmaking industry of the Levant and Egypt supplied glass to much of the world in the late antiquity—from Cyprus to Italy and, eventually, Africa. For reasons that will soon become clear, there is an assumption that the transparent blue high-quality natron glasses uncovered in Kadhima and Shiqaya could have been fused and worked in the Sharon Plain, then exported to Baṣra, located close to the general maritime route connecting the Persian Gulf with the East African coast. This model seems to apply to the contemporary Unguja Ukuu natron glasses where chemical element analysis confirmed the hypotheses that the Sharon Plain, rather than any other region outside Levant, was the place where the Unguja Ukuu natron glasses were produced, fused and traded as far as the East African coast.

According to Blair (Blair,2016), in his attempt to establish the trade pattern between Unguja Ukuu and the Kuwaiti sites, the major city of Baṣra was probably the source of the glass vessels for those sites, whether or not the glass itself was actually produced and worked there. Current chemical analysis of pinched and trailed decorated natron glasses from Unguja Ukuu demonstrates that the specific glass itself was produced in the Sharon Plain. The majority of the vessels bear pinched and trailed decoration and must also be produced and worked in the Sharon Plain. Trace elements analysis shows that vessels with this type of decoration were a speciality of

the Levant. More specifically, in Levant existed a workshop or workshops specialised in the practice of the hot-working technique, that used decorative trails or pads of glass applied to the hot surface of the vessel (Goldstein,2007:15;Henderson *et al.*,2016:142). This is an indication that the trailed decorated natron glasses from Unguja Ukuu were probably fused and worked in the Sharon Plain; from Levant could have been exported eastward to Baṣra for further shipping to Unguja Ukuu. If the high-quality blue natron wares from Unguja Ukuu came from Baṣra, as products of export from the Levant, it is not strange to assume that the ***Levantine I*** type of wares from the Kuwaiti sites were also fused in those workshops.

Three points must be made here. First, chemical analysis shows that the scratched decorated vessels were made from a combination of ashed halophytic plants and sand, as the majority of the Unguja Ukuu glasses were, in both northern Syria (perhaps in al-Raqqa) and Iraq, with the glass and the vessels being made in Sāmarrā (Henderson *et al.*,2016). Blair, writing on the topic, noted that it seems that glass as a trade item was not on demand in Unguja Ukuu or of much concern for the inhabitants, since it was rarely found, possibly suggesting it was unaffordable or was not selected by the merchants (Blair,2016:297). The second point to be made is that the pinched decorated fragments (nine in total) and the trailed-decorated fragments (four) came from the Levant (a place of specialisation). Finally, the third point is that the open vessels with plain rounded rims dated to the 9th century AD came from Iraq, the open plain rims, the open plain thick rims, the open plain fine rims and the open triangular beaked rims apparently came from the Levant and the more elaborate variation of the open vessels with the stepped rims dated to the 8th century AD probably travelled from northern Syria.

Another observation is important here: the majority of the glasses from Unguja Ukuu (the open vessels) came from the Levant and northern Syria. The preference of this specific type of vessel, which had to travel a long distance, was probably related to the mechanism of the trade, as an open form could be easily transported and stored for shipping. Faced with the problem of interpreting the results, it can be said that open vessels from the Levant and northern Syria tended to play an active role in material life in Unguja Ukuu either for serving, eating, drinking or as an item on display, and it was probably affordable, functional or socially valuable (Blair,2016:294). A glance through the chemical analysis results of the more unusual types, such as the 8th century AD ribbed necked vessels, vessels with closed flaring rolled-in rims and a wide necked vessel, indicates that they were probably made in Iraq (Sāmarrā, Baghdad or Başra) and travelled a shorter distance. There are some exceptions: the closed necks and shoulder, a ribbed neck and closed vessels with rolled in rims were probably moved from the Levant. Blair points out that

those closed and semi-closed vessels were traded by the merchants as storage or container items for liquids (perfumes, cosmetics or medicines) or precious commodities (spices) (Blair, 2016:295). At this point, it is not possible to locate the exact ports from which the vessels produced in Syria, the Levant and Iraq came from, but the presence of the same types in Kadhima, Shiqaya, Mughaira and Sīrāf points to Baṣra or Sīrāf . It seems likely that the vessels arrived in Unguja Ukuu as a result of the Persian Gulf trade and that Baṣra should be looked at as the possible port of export. Nonetheless, the presence of Iraqi glasses in East Africa suggests there was commercial contact between the Persian Gulf ports and East Africa.

7.2.2 Plant-ash glass

Leaving aside natron type glasses uncovered in Unguja Ukuu, we now come to the quantitative and qualitative chemical analysis results of the plant ash glasses. The first group, designated here as ***Group I***, consisted of 26 vessels having the lowest concentrations of alumina and lime. While we can recognise that those concentrations must have an Iraqi/Iranian provenance, it is noteworthy that the majority of the samples (n=19) have similarities with the Sāmarrā glasses; the other samples are closer to Sīrāf, Nishapur and Ctesiphon. Nineteen vessels were clearly distinguishable from the others having the lowest concentrations of lime and have similarities to the green cut vessels that were made in Sāmarrā (Henderson *et al.*,2016:142). Sāmarrā was the place of production for the 'ice-blue' (pale blue glass, almost colourless, with no green hue) glass used for eight vessels with relatively plain, slightly thickened and rounded rims. It is especially interesting to note the high standardisation of colour; every plain-rounded rim in Unguja Ukuu was produced with 'ice-blue' glass from Sāmarrā. The only exception is GL1620 which shares the same colour but belongs to ***Group II***. Nonetheless, it still has remarkable standardisation. The above vessels, dated probably to the 9th century AD, make up the most common type at Unguja Ukuu (142 samples) and were associated with a variety of functions, perhaps for eating or drinking or display (Blair,2016:107). The trade of plain rounded rims of 'ice- blue' glass from Sāmarrā was rare at the Persian Gulf sites of Kadhima, Mughaira and Shiqaya (1 sample identified). One type was identified at Sīrāf , at Shanga dated to 800-1000 AD, at Kilwa to the Period Ia/Ib, and possibly at Manda, but there is no information from chemical analysis results

to prove if the glass was produced in Sāmarrā (Blair,2016:107).This would be an interesting project for future research.

On the whole, it seems that the standardisation of the colour, the type of the rim and the raw glass material observed in the plain rounded rimmed vessels led us to reasonably assume the existence of a workshop specialised in their production. The existence of an atelier/s in Sāmarrā where the 'ice-blue' vessels with plain-rounded rims could have been worked should be forgotten. Although the foundations of glass workshops (furnaces) or slag glass were not uncovered during Samara's excavations, scientific and archaeological historians are aware of their existence (Lamm,1928:4;Henderson *et al.*,2016:139,142). In his book 'Das Glass Von Sāmarrā' (1928), Carl Johan Lamm wrote that it is firmly believed that Sāmarrā, alongside the neighbouring town of Tigris Ort Qādisīyah, was a glass manufacturing centre, at least for window glass, glass for wall decoration, for bottles and undecorated vessels (Lamm,1928:4). Current compositional data has also shown that from the same raw glass (ice-blue) produced in Sāmarrā, the following vessels were also made: a ribbed neck vessel, a wide neck vessel, two ring bases, an open vessel with an inward folded rim, and finally a vessel with a rolled-in rim. The assumption of the existence of a secondary workshop in Sāmarrā is further supported by an 'ice-blue' pinched decorated fragment (GL0470) that belongs to the same group. Previous chemical analysis conducted by Henderson and his colleagues shows that a pinched decorated bowl together with four pale green mould-decorated vessels, now in the Museum for Islamic Art in Berlin, were probably made in Sāmarrā's workshops. During the early Islamic period, Sāmarrā's workshops developed a new artistic language of stylised palmette motifs that are demonstrated in a range of techniques practised there, such as pinching and moulded decoration (Lamm,1928:136;Henderson *et al.*, 2016:137). Whether the pinched decorated fragment was worked and fused at those workshops is, of course, unknown.

Attention should be drawn to a trailed decorated vessel (GL0213) and a lug handle (GL802) that, on the basis of aluminium and calcium concentrations, are linked to Sāmarrā, although it cannot be stated with certainty that they were worked in Sāmarrā. The other trailed decorated sample (GL3461) that has the highest concentration of lime has similarities to the green wheel cut facetted glasses produced, fused and worked in Ctesiphon, which is 84 miles away from Sāmarrā. This, of course, does not necessarily mean that the vessel itself was worked there. When examining the ***Group I*** glasses in conjunction with the glass from Iranian sites, it is immediately clear that the wide neck (GL382) and an open plain thick vessel are similar to the main ***group I*** produced at Sīrāf . This is, of course, something to be expected as the literary sources indicate

contact between the two places. At this point, we touch upon an intriguing issue. This is the first time after chemical analyses conducted by Swan and his colleagues that we can prove that glass produced at Sīrāf was exported to the East African coast in Unguja Ukuu, Zanzibar. This fact is an indication, if not of trade, then of exchange between the Persian Gulf port of Sīrāf and Zanzibar on the East African coast. The most important of ***Group I s***amples was that of GL0090 (***Figure 7.2.2.1***), which possesses an intricate level of well executed scratch-engraving cut decoration. The blue glass fragment, decorated with white bands of parallel and perpendicular straight lines and three triangles in a chevron pattern, is similar to the Sāmarrā glasses. It has long been suspected that deliberately coloured glass through the addition of cobalt or copper blue glass was produced in Syria (al-Raqqa) or Mesopotamia (Sāmarrā), and now Sāmarrā seem to be proven scientifically. Its identification is an important fact, in the knowledge that glassmakers in Sāmarrā were trying to produce vividly coloured blue glass, using cobalt or copper, appropriate for the execution of quite a sophisticated technique.

Scratch-engraved vessels have also been found in ***Group II*** which is related to northern Syria. Two scratch decorated vessels, GL2846 and GL2244, have similarities to vessels produced in northern Syria. But this is not surprising. Recent chemical analysis of vividly coloured glass uncovered in the crypt of a stupa in the Famen Temple, Shaanxi Province, China, has shown that some vessels were made at a specialised site or zone, perhaps in Syria, while a sample was also made in Nishapur. This type was related to northern Syria, Sāmarrā and Nishapur. The scratch-engraved vessels from Unguja Ukuu will be compared with those analysed by Robert Brill and those uncovered in the Famen Temple and analysed by Julian Henderson. ***Figure 7.2.2.2*** shows the comparison. It is especially interesting that the blue stepped rim, GL 2244, (decorated with a chevron pattern of triangles within a section defined by two horizontal lines), and the blue GL2846 (with a less complex design, consisting of no more than two straight lines), are similar to glasses produced in northern Syria, with three samples from the Famen Temple: a blue dish, 1988-0141 (with a maple leaf pattern), a blue glass dish, 1988-0129 (with eight floral patterns) and a blue glass (with string patterns).



Figure 7.2.2.1*: High-magnesia scratch-engraved glass (GL0090)uncovered in Unguja Ukuu, Zanzibar.*

Unguja Ukuu scratched glasses also have similarities to three glasses analysed by Robert Brill: a colourless with a slightly yellowish tinged plate, 6343 (with central four-lobed motifs alternating with three-lobed motifs), a dark blue large plate, 6349 (with central seven-lobed florets, with hatching and rope motifs) and finally a large dark blue plate, 6350 (with central florets of eight spiked petals alternating with four-lobed blossoms, with hatching, rope, leaves, and opinion that the workshop/workshops in northern Syria, perhaps in the vicinity of al-Raqqa, were specialised in the production of this specific glass (Carboni, 2001:81;Li *et al.*,2016:175). Nonetheless, there is a possibility that the vessels made at one site could have been transported elsewhere to be decorated. Their presence alongside the open-stepped rims, closed flaring straight and open triangular beaked rims, as shown in subchapter 6.2, suggest that they must have been worked in northern Syria, leading to the assumption that Syria was probably the place where craftsmen worked these vessels.

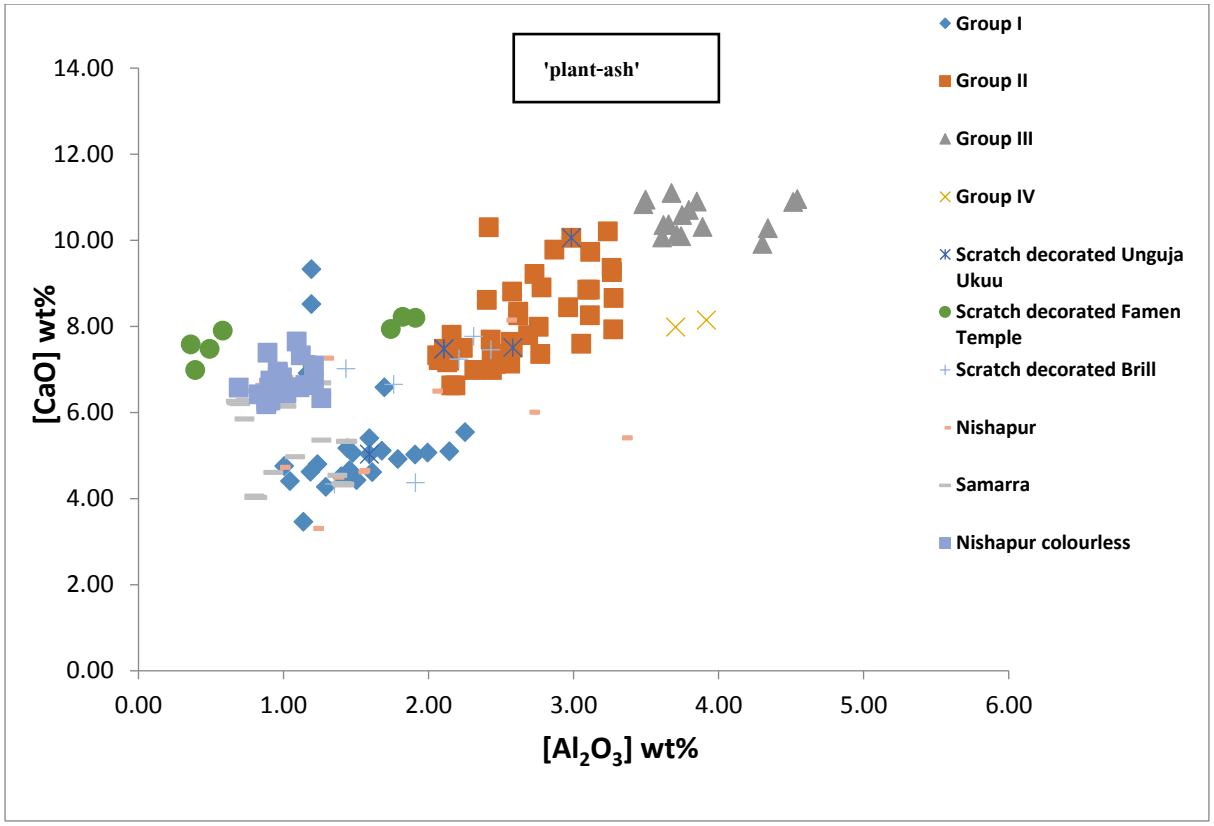


Figure 7.2.2.2: *Plot of aluminium versus lime for scratch-engraved glasses from Unguja Ukuu, Zanzibar and other scratch-engraved glasses.*

In ***Figure 7.2.2.2.***, it can be seen that the mean values of CaO and Al_2O_3 in two scratch decorated Unguja Ukuu glasses, GL2244 and GL2846, are similar to glasses produced in northern Syria and scratch decorated glasses studied by Brill (Brill,1999:196). All have alumina greater than 2% and lime around 7.50%. The scratch decorated Unguja Ukuu glasses are generally are closest to those in Famen Temple; the lime levels are about the same but the alumina content are lower less than 2%. The similarities of the scratch decorated Unguja Ukuu glasses with scratch decorated glasses studied by Brill could suggest that were made in the same location. In this next section, a trailed zigzag patterned fragment, GL2975, will be discussed. The olive-green fragment with a protruding trail (that would have been attached to the vessel along its long axis and would have protruded from the vessel) was uncovered at Unguja Ukuu among other trailed threads that were intended to protrude from the host vessel, threads that were trailed in a flat pattern and possible trailed handles (Blair,2016:152). Through chemical analysis, it was shown that the fragment belongs to the same group as other vessels from northern Syria. Stefano Carboni's catalogue demonstrates how zigzag trailing has its roots in the late antique tradition in the Syrian area (Carboni,2001:176).

A rare component of the early Islamic glass tradition, the millefiori or mosaic glass number GL3145 (***Figure 7.2.2.3***) (only two fragments were unearthed during the archaeological excavations in the ´Abbāsid capital of Sāmarrā) (Carboni,2001:29;Blair,2016:146). The history of this type of glass was the most fascinating, as it has appeared in Egypt about 1400 BC, and disappeared and reappeared in Mesopotamia in the ´Abbāsid capital (836-892 AD), Sāmarrā, in the 9th century AD, or perhaps even earlier (Carboni,2001:29;Blair,2016:146). It was said that the caliph of Sāmarrā himself or his advisers inspired the production of the millefiori glass for the construction of a floor of the throne room and the harem of the palace, Jawsaq al-Khāqāni, to provide an effect of walking over a multicolored, brilliant, and reflective layer of cold glass (Carboni,2001:30). For the purposes of this investigation, it is important to locate which geographic area of production the millefiori fragment with the 'bulls-eye' pattern belongs to (the pattern starts with a bright turquoise core, with consecutive rings of white, red, yellow, green, and then yellow slices). While we might have expected the fragment to bear similarities to the fragments belonging to ***Group I***, to our surprise the chemical analysis has shown similarities to the fragment belonging to ***Group II***.

Leaving aside the small number of decorative fragments, it is interesting to look at the majority of samples belonging to ***Group II***. Generally speaking, it is wise to keep in mind which types of vessels were coming from northern Syria. ***Group II*** comprises mainly the most distinctive types, increasingly well recognised, of the early Islamic glass tradition: the open stepped rims, the open flaring straight and the triangular beaked rims (Blair,2016:87). More information about those vessels as products of a Syrian specialised production are provided in subchapter 6.2. As it has been shown earlier, a wide variety of vessels were fused by glass produced in northern Syria; more specifically, there must have been a workshop/workshops specialised (due to the high level of standardisation in rims) in the production of these three types. Syria appears to be one of the greatest markets for Unguja Ukuu. The presence along the East African coast of a great number of vessels produced in Syria is an issue that must be discussed. One can hardly fail to see that the merchants or inhabitants of Unguja Ukuu selected certain types of vessels from Syria. While it remains unclear whether this was created by the interests of the merchants or the sellers from the Syrian markets, the fact is that the above vessels were widely distributed and popular.

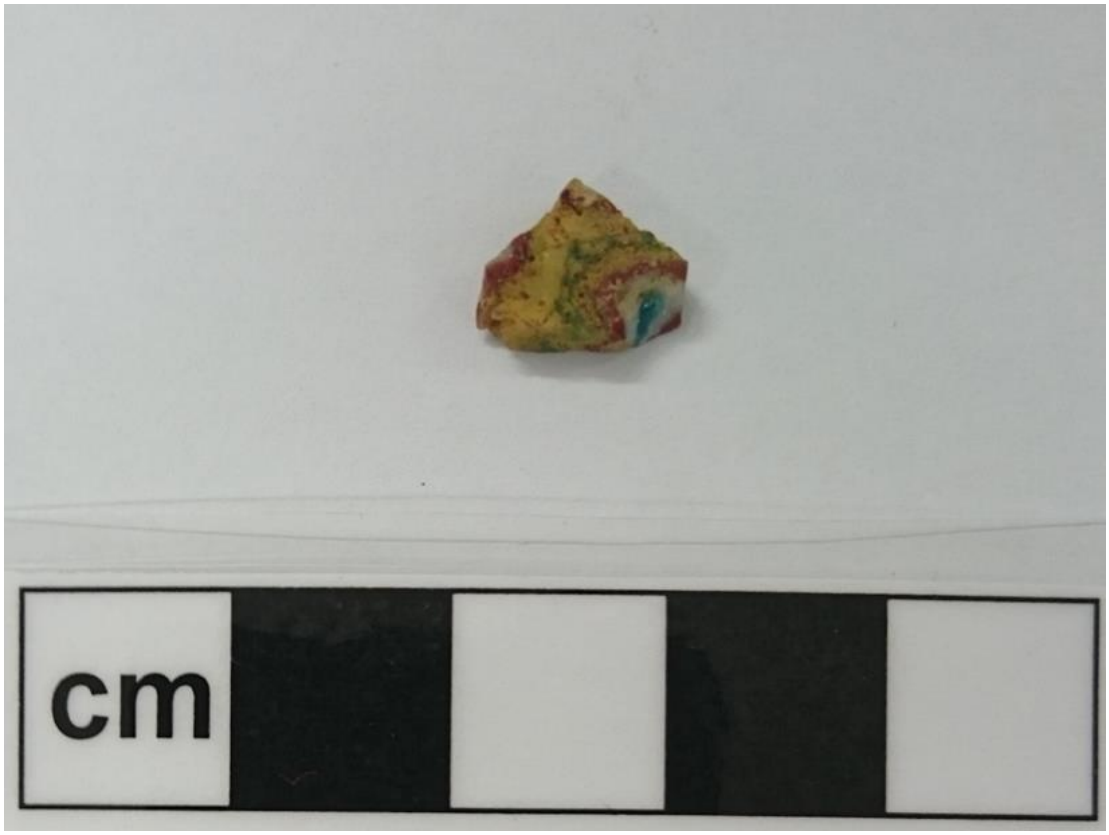


Figure 7.2.2.3*: High-magnesia millefiori glass (GL3145) uncovered in Unguja Ukuu, Zanzibar (photo by the author).*

The next issue to discuss is two fragments decorated with the technique of trailing (Blair, 2016:149). The olive-green flat trailed fragment, GL3257, uncovered in Unguja Ukuu belongs to what was designated as ***Group III*** in this study. It seems that this glass, which survived the application of threads joined to the host vessel in the same olive colour, was produced at an unknown place, perhaps somewhere in Iraq. Whether the vessel itself was fused at the same place, we cannot say. But this trailed decorated fragment was not the only one belonging to ***Group III***. Another fragment, GL3306, from the same group, presents a similar way of working; it differs only in the more linear trail applied on an olive-green vessel (Blair,2016:153). As was expected, a closed and semi-open folded and flattened rim belongs to the same group. Since previous chemical analysis of the Kuwaiti samples shows that those types were probably a speciality from an unknown place, it was, of course, tempting to think that due to these similarities, the Unguja Ukuu samples were products of the same workshops. From the fourteen samples uncovered there, two were analysed. Previous analysis of the Kuwaiti samples clearly shows that this specific type was also a speciality of northern Syria's workshop/workshops. As far as can be made out, ***Group III*** represents similar fragments, the plain (thick) and the plain fine rims. Despite the large

amount of samples discovered both in Unguja Ukuu and the Kuwaiti sites, a limited number are analysed in the current study. Whether they came from the same specialised glass workshop, we cannot say with certainty because there is little to link them apart from their thickness (most of the samples are individually unique and fragmentary, with a diverse range of colours) (Blair, 2016:114). It is thought that because of their fragility, they were not traded between the Persian Gulf and the East African coast on a frequent basis (Blair,2016:114).

Finally, ***Group IV*** consists of only two samples, sample GL3255 (a closed flaring straight) and GL2100 (a closed neck and shoulder). The group is distinct from, but has similarities to, twenty-eight samples from the Kuwaiti sites that are characterised by a homogeneity of the samples, attributed to the fact that they all belong to the most intact vessel found within the confines of the east room, in deposit (Blair,2016:179). It is difficult to locate the origin of this group. Apart from the similarity with the twenty-eight vessels from the Kuwaiti sites, ***Group IV*** is similar to sample 5340 from Hamadan, a neighbouring region of Nishapur. The sample was an aqua vessel which possesses decoration on a mould-blown dimpled body; normally, the sample is dated to later than the ***Group IV*** glass (late 7th to 8th century AD as opposed to the 10th or 11th century AD). As far as can be made out through comparison with other places, it is not possible to discover its origin. It seems possible that from a specific unknown glassmaking or glassblowing centre, specific types of vessels found their way to Kadhima, Shiqaya and Unguja Ukuu. But chemical analysis cannot prove where exactly that location was. It has been shown also that the Group IV glass has similarities to four samples from Tell Zujaj of Type 4, which were fused there but are clearly distinct. Finally, we must mention the two dark green transparent glasses and a yellowish green sample from Nishapur that are similar to Group IV glass. All three of the samples bear decoration: 3082, the alabastron, bears facet-cutting, while the 5301 and 5302 bottles possess molded decoration (Brill,2005:85). At the end of this subchapter, it must be acknowledged that there are a number of difficulties in the interpretation of glass compositional groups, leading to a kind of guesswork when published data is not sufficient. Future research and more chemical analysis results would be helpful.

CHAPTER 8

CONCLUSIONS

8.1 Sources of glass in the 7th and 9th century AD in the Persian Gulf and in Unguja Ukuu

This thesis has examined glass shards from Kadhima, Mughaira and Shiqaya in the Persian Gulf and Unguja Ukuu on the East African coast, and has shed light on glass production and trade. The most important contribution of this thesis is that chemical analysis has shown the presence of a previously unknown plant ash subtype that does not resemble other known ashes from contemporary early Islamic sites. The specific subtype, designated here as ***Group III***, is typically characterised by the distinctly different levels of soda and silica and by exceptionally high aluminium and lime concentrations. Glass showing this characteristic elemental feature is in stark contrast to all published glasses. Typically, naturally-coloured light green-blue glass (with a large range of shades and hues), to naturally-coloured bright 'emerald' green or olive-green glass, has been identified in large quantities only in Kadhima, Mughaira and Shiqaya in the Persian Gulf and in Unguja Ukuu on the East African coast. This new subtype reminds us of the gaps in our knowledge of the history of glassmaking in and around the Persian Gulf. A further important contribution of this thesis is that the study of the chemical composition of this subtype has proven the production of plant ash glass probably east of Euphrates, somewhere in Iraq judging from the plant ashes used.

Focusing on glass shards of ***Group III***, their presence in large numbers at the above sites, coupled with their total absence elsewhere in the Islamic world, could say something about glass trade in the western Indian Ocean. The very presence of a rare subtype at the Kuwaiti sites and at Unguja Ukuu suggests that the Persian Gulf ports during the 7th to 9th centuries AD (a time in which Islam become the driving force behind long distance trade in the western Indian Ocean) were actively engaged in glass trade with Unguja Ukuu on the East African coast. Interestingly, the idea of glass as a trade or exchange item from the Persian Gulf ports to as far as Unguja Ukuu is a significant contribution of the thesis, proving scientifically what has long been suspected based on historic and literary sources. Those early medieval geographers and travellers, who are equally valuable, give us a panoramic view of life in the early Islamic world, providing general information about products, merchants, harbours, coasts, stages of voyages, captains, seamen and their

languages; but this information is not enough to illuminate the glass trade (Ricks,1970:344;Hourani,1995:67;Daryaee,2003:3;Whitcomb,2009:72). This thesis has clearly shown that if we solely relied upon the occasional notes and the geographers' descriptions, then much of the Persian Gulf glass trade would be invisible.

The glass samples analysed include a range of 'iconic' early Islamic decorated vessel forms including pinch-decorated, trail-decorated and scratch-decorated types. Other plainer, more common vessel types included blue plates and vessels with plain rounded rims, open stepped rims and open triangular beaked rims. Interestingly, the last important contribution of this thesis is that from our compositional data there is some evidence for specific regions providing specific vessel forms and types found at Kadhima, Mughaira, Shiqaya and Unguja Ukuu. This includes the pinch-decorated vessels made primarily in the Levant, scratch-decorated plant ash glass vessels in northern Syria and Iraq, 9th century AD vessels with plain rounded rims made in Iraq (perhaps in Baṣra), and 8th century AD vessels with open stepped rims in northern Syria (perhaps in al-Raqqa). More evidence for regional traditions is given by Kato *et al.* (2009), who have shown that the majority of the lustre painted natron vessels they analysed were made with ***Egyptian II*** glass. Also, in contrast to the 'inland' production of scratch-decorated vessels in Sāmarrā, Iraq (Henderson *et al.*,2016), in Syria (possibly al-Raqqa) and Iran (possibly Nishapur) (Li *et al.*,2016) Kato *et al.* (2009) have shown that scratch-decorated vessels were also made with Egyptian (natron) glass. It is therefore clear that while the various styles of scratch-decoration might be considered specialised products, the glass used to make the vessels and probably the vessels themselves were made in a number of centres across the Middle East.

To summarise the chemical analysis results, the majority of Kadhima, Mughaira and Shiqaya glasses were found to be plant ash soda glasses divided into four subtypes with different alumina and lime concentrations (here designated as ***Group I***, ***Group II***, ***Group III*** and ***Group IV***) revealing the use of different silica sources. The ***Group I*** glasses are chemically similar to Iran/Iraq glass. This category contains glass mainly from Ctesiphon but also from Sāmarrā and Nishapur. Seven vessels from ***Group I*** were clearly distinguishable from the others, having the highest concentration of lime. Those vessels resemble glasses from Ctesiphon; the other samples resemble glasses from Sāmarrā and Nishapur. An important observation was made, which is that out of all the Iranian and Iraqi glassmaking workshops, there was a preference in Kadhima, Mughaira and Shiqaya for glasses produced in Ctesiphon. In contrast, in Unguja Ukuu there was a preference for glasses produced in Sāmarrā. ***Group II*** was similar to the glasses produced in a different zone or location. More specifically, the glasses have characteristically high magnesia

and was similar to ***Type II*** glass from Tell Zujaj, al-Raqqa. ***Type II*** glass was made in Tell Zujaj from the late 8th to early 9th century AD. Syria was one of the greatest sources of glass for the Persian Gulf coast. ***Group III*** and ***Group IV*** were related to unknown sources that must have been located east of Euphrates, perhaps in Iraq. In one essential respect, ***Group III*** differs from all the other major centres. Without trace and isotope analysis, we are limited in what we can say about the provenance of the group. It will be interesting in the future to use such analysis to confirm whether Baṣra in Iraq was the centre of the production of ***Group III*** glasses.

A word, finally, about two mineral-soda glasses uncovered at Kadhima and Mughaira. In fact, the natron glasses overlap between ***Levantine I*** and ***Levantine II*** types, but fit closer the oxide profile for ***Levantine I*** glasses. The ***Levantine I*** glass was greenish or transparent blue and of high quality, with occasional bubbles (Tal, Jackson-Tal, Freestone,2004:56;Freestone,Jackson-Tal, Tal,2008:68). Through chemical analysis results, conclusions can be drawn with reasonable certainty about the source of the mineral-soda glasses uncovered at Kadhima and Mughaira. The same greenish (light-green blue) and transparent ice blue colour is obtained in high quality natron glasses from Kadhima and Mughaira. Whatever the exact colour and quality of these glasses, chemical analysis results suggest that the vessels from the Persian Gulf could be made by raw products from those furnaces in the Levant. But it is impossible to say whether the vessels were fused in Apollonia-Arsuf in Sharon Plain in Israel. The Sharon Plain in Israel has a dozen sites related to secondary production, and ***Levantine I*** type glass could have been fused there or outside of Levant, as the excavations at al-Raqqa show (Tal, Jackson-Tal, Freestone,2004:59).

To summarise the chemical analysis results, the majority of Unguja Ukuu glasses from the East African coast were found to be plant ash soda glasses divided into four subtypes with different alumina and lime concentrations (here designated as ***Group I***, ***Group II***, ***Group III*** and ***Group IV***) revealing the use of different silica sources. The major and minor elements indicate that the majority of glasses are of soda-lime-silica composition made from a combination of ashed halophytic plants and sand. Only 19 samples are soda-lime-silica glasses, with low potash and magnesia. ***Group I*** plant ash comprised of 26 vessels, having the lowest relative concentrations of alumina. The overall picture is that levels of lime below 8% and alumina below 2% assume an Iraqi or Iranian source (Henderson *et al.*,2016:138). The majority of ***Group I*** (including scratch-engraved, pinched and trailed fragments) bear similarities with glasses produced at Sāmarrā. Two glasses overlap with glasses from Sīrāf, one sample with glasses from Nishapur, and three, including one trail-decorated fragment, with glasses from Sāmarrā. Finally, it should be noted that a trail-decorated fragment was produced at Ctesiphon. There was a preference in Unguja

Ukuu for glasses produced in Sāmarrā. In contrast, there was a preference in Kadhima, Mughaira and Shiqaya for glasses produced in Ctesiphon. ***Group II*** comprised the majority of the vessels (n=39). It is noteworthy that glass from ***Group II*** resembles the chemical composition of al-Raqqa ***Type 2*** glass from Tell Zujaj, Syria, a fact that supports an assumption of a Syrian centre of distribution (Henderson,1999:438;Henderson *et al.*,2004:452;Henderson *et al.*,2016:138).

Through examining the 39 samples, it was obvious that Syria was the greatest market for Unguja Ukuu, as with the Kuwaiti glasses. The presence on the East African coast of a great number of vessels produced in Syria is an issue that must be further explored. It seems that in Unguja Ukuu, merchants or inhabitants selected certain types of vessels from Syria. While it remains quite uncertain whether this selection was created by the merchants themselves, or whether specific types were promoted from the Syrian markets, the fact is that the above vessels were widely distributed and popular. ***Group III*** and ***Group IV*** glasses were related with unknown sources. ***Group III*** comprised of 14 vessels, typically characterised by distinctly different levels of soda and silica and by exceptionally high aluminium and lime concentrations, probably related to an unknown source east of Euphrates, perhaps in Iraq. In comparison with ***Group III*** glasses from the Kuwaiti sites, ***Group III*** in Unguja Ukuu was not at all the most dominant group.

Finally we consider the nineteen mineral-soda glasses uncovered at Unguja Ukuu. Three groups were identified. The first group, ***Group 1***, consists of two push-up bases and a ribbed-neck with low Al_2O_3 and high CaO. The majority of glasses fit within ***Group 2***, consisting of 16 glasses with high Al_2O_3 and high CaO. All of the pinched-decorated fragments, with the exception of one sample, belong to this intermediate group. Other samples from this group include a trail decorated fragment, one plain-rounded rim, two lugs-handles, one closed-flaring neck, and one applied-base. ***Group 3*** consists of only two samples, a plain-rounded rim and a pinched-decorated fragment with high Al_2O_3 contents. The cluster of the three glasses in ***Group 1***, two push-up bases and a ribbed neck, seems to be associated with ***Egyptian II*** glass. The sixteen samples defined as ***Group 2***, most of them with pinched decoration, the applied base, the two lugs-handles, the closed-flaring neck and the plain-rounded rim, seem to be associated with ***Levantine I*** glass (Freestone *et al.*,2000). ***Group 3***, which consists of one plain-rounded rim and a pinched-decorated fragment, overlaps with the ***Levantine II*** group that is associated with the large-scale manufacturing installations at Bet Eli'ezer, near Hadera in Israel.

The findings from this thesis show the variety of sources of glass uncovered in the Persian Gulf and the East African coast. The thesis also highlights the preferences for specific sources.

Whether this preference is related to demand, or the choice of the merchants and traders, or the trade relations with specific places, it is impossible to say at this stage. This demands further research as a number of difficulties in the interpretation can be encountered. This could be an interesting future proposal for research. Leaving aside those considerations, the current thesis enhances our knowledge of glass production and trade at the Kuwaiti sites and in Unguja Ukuu on the East African coast, and opens up a number of exciting possibilities.

8.2 Were Sīrāf and Baṣra early glass production centres for glass in the Persian Gulf?

Any history of glass production in the Persian Gulf will necessarily focus on its port cities, Baṣra and Sīrāf, those 'brides of the sea', connecting the Islamic world with the Indian Ocean and the wider world (Potter,2009:4). A number of glass fragments were uncovered in Kadhima, Mughaira and Shiqaya in close proximity to Baṣra and Sīrāf, dated back to the 7th until the 11th centuries AD. Those Persian Gulf ports did not themselves constitute a significant market as their main function was to forward goods to the interior or to redistribute them to other ports (Potter, 2009:4). During the Umayyad period (661-750 AD), a large Arab population settled in Baṣra, a garrison city with a strategic location; the city was located far up an inland river, the Shatt a-Arab, which allowed it to become a major port at the head of the Persian Gulf, where goods from Muscat or Sīrāf could be transported there by smaller ships for further transportation on seagoing ships (Whitcomb,2009:71;Potter,2009:4). The entrepôt was located on the southern coast of Iran, and was well connected to Baṣra, Oman and Shiraz. This facilitated the expansion of shipping across the wider Indian Ocean and East Africa (Whitehouse,1983:328). With the accession of the ´´Abbāsid dynasty, there was an impetus to trade across the sea to and from the Persian Gulf (Hourani,1995:64). The Persian Gulf ports were well connected with the new capital Baghdad, a vast centre of wealth and luxury, in the heart of the rich plains of Mesopotamia and between the Tigris and Euphrates rivers. Every ship that travelled on the Tigris could go up to Baghdad and anchor there, and goods could be transported on the Euphrates to Baghdad to be unloaded there for further shipping to Baṣra or Sīrāf and then to the wider Indian Ocean (Hourani,1995:64).

Since the discovery of artistic glass wares during excavations in Kadhima, Mughaira, Shiqaya and Sīrāf, a number of questions were raised. The most important for this thesis was whether the glass wares were products of a local glass production centre or products carried there either on boats or by camel or donkey from the caravan routes. Regarding the origin of the glassware uncovered in Kadhima, Mughaira and Shiqaya, there is no evidence from the excavations that glass was produced there. There are absolutely no remains of glass working at any of the Kuwaiti sites (Blair,2016:341). Andrew Blair, who conducted typological analysis of the vessels, was of the opinion that Baṣra, less than a week's caravan journey, was the source of glass, whether the glass itself was actually produced or worked there (Blair,2016:341). Archaeological excavations

have never been undertaken at Baṣra (Mason,Keal,1991:52). Without excavation, the most definitive evidence of glass production would be the identification of a distinctive elemental composition from chemical analysis results but still it needs to be linked geologically to the location. There was a strong possibility that Baṣra was the possible production centre for the Iraqi glasses of ***Group I***. But after the comparison with data from Sāmarrā and Ctesiphon, it was proved that the majority of the Iraqi vessels were made by glass produced and probably fused at Ctesiphon or at Baghdad (see ***Group I*** in previous subchapter 7.1.2). The others were produced and probably fused at Sāmarrā. If glass was produced at Baṣra, it would have a distinctive elemental composition. Henderson and his colleagues, using trace element analysis, have shown that glass made at al-Madā'in (Ctesiphon) has a characteristic elemental composition distinctive from glass produced in Sāmarrā (Henderson *et al.*,2016:142). But among the Iraqi/Iranian glasses of ***Group I***, no other distinctive elemental compositions were observed that could lead to the assumption of a different source.

The next issue is whether ***Group III*** glass, produced east of Euphrates, perhaps somewhere in Iraq, was related with Baṣra. But at this stage of the thesis, without trace or isotope analysis, it cannot be said with certainty. ***Group III*** was recognised in 26 shards in Unguja Ukuu. The glass finds were clustered throughout the depositional sequence at Unguja Ukuu, in association with quantities of Near Eastern ceramics (white glazed and turquoise glazed from Iraq and/or Iran) (Wood *et al.*,2015). Mason and Keall (Mason,Keal,1991) scientifically analysed white glazed and blue-green (often called turquoise) glazed semi-luxury wares that were widely distributed, and suggested that they were ceramic products of Baṣran kilns or nearabout. Their analysis proved to be of great archaeological importance as those wares are the most diagnostic for early Islamic occupation in the entire Gulf region and indicative of a large commercial interaction (Mason, Keall,1991:52;Potter,2009:74). If the imported pottery in Unguja Ukuu was a product of the Baṣran kilns, Blair's assumption that the origin of the Kuwaiti and Unguja Ukuu glasses was the Baṣran kilns seems reasonable. It will be an interesting future proposal to study ***Group III*** to identify whether these Iraqi glasses were also products of Baṣran furnaces and exported together with white glazed and blue-green (often called turquoise) glazed semi-luxury wares across the wider Indian Ocean.

It was tempting to think that the great entrepôt Sīrāf in the 10th century AD, located on the north shore of the Persian Gulf, Iran, was a source of glass for the Kuwaiti glasses. In Sīrāf, the principle evidence for glass production can be seen in the so-called 'local' glass (Whitehouse,1970:18; Swan *et al.*,2017:115). Swan and her colleagues recently chemically analysed glass from Sīrāf to

address issues of glass production and trade in the Persian Gulf (Swan, *et al.*,2017). The analysis proved to be very helpful for the thesis, illuminating that glass south of the Persian Gulf was traded in Unguja Ukuu and not from Sīrāf. The most interesting of the archaeological remains in Sīrāf was a glass kiln discovered alongside kilns devoted to the production of ceramics. Also, a rubbish pit contained many fragmentary glass vessels and glassworking debris (drops, trails, etc.) were uncovered (Whitehouse,1968:5,12). Whitehouse was of the opinion that a type of glass, designated as local glass, was produced locally, a fact that was proven by chemical analysis (Swan *et al.*,2017:115). There is reason to confirm whether local glass from Sīrāf was traded either to the north (Kadhima, Shiqaya and Mughaira), to the south (Unguja Ukuu), or the reverse whereby the glasses reached the north Persian Gulf coast from northern Syria and Iraq and were traded to Sīrāf and then to Unguja Ukuu. By comparing the Unguja Ukuu glasses with three Kuwaiti sites and Sīrāf, it can be seen that not all the compositional types uncovered in Unguja Ukuu and in the Kuwaiti sites have been recognised in Sīrāf.

The most interesting finding was the absence in Sīrāf of the rare ***Group III*** glass, uncovered both at the Kuwaiti sites and at Unguja Ukuu, and the widely distributed northern Syrian glass. Another interesting observation was the absence of local glass produced in Sīrāf both to the north (Kuwaiti sites) and the south (Unguja Ukuu). A single fragment, a vertical neck (GL1337), unearthed in Unguja Ukuu, overlaps with the Main Group 1 from Sīrāf. But the presence of a single fragment from the Sīrāf kilns found in Unguja Ukuu site cannot be seen as evidence of participation in the glass trade system, as it may well have arrived there by hand to hand exchange. The mere fact that Sīrāf's local glass has not been found on the East African coast or in closer proximity to the Kuwaiti sites could justify the conclusion that it was not an export product but was probably intended for daily use. Moreover, the inferior quality of the majority of the glass, with the presence of bubbles, can support an assumption like this. In fact, it is logical that this type of glass was absent from the above places, because during our period of interest the specific type of glass was even rare in Sīrāf. Whitehouse noted that it was rare before 825-850 to 977-1055 AD and then became the dominant type (Swan *et al.*,2017:103). The key to glass trade lies in research of the 'East Persian' type of high-quality colourless or nearly colourless glass often adorned with wheel-cut or carved decoration uncovered in Sīrāf (Swan *et al.*,2107:103). Whitehouse mentioned the similarity of that type of glass, designated as 'Low Zirconium' glass, with glasses uncovered in Nishapur. By comparing this type with Kadhima, Mughaira, Shiqaya and Unguja Ukuu glass, we can see the similarities with eastern glasses from Iraq, including Ctesiphon. One exception is a dark blue low zirconium glass (GL009) from Sīrāf that provokes

confusion. It has similarities with a closed ribbed neck fragment (GL1264) from Kadhima. Nevertheless, Swan and his colleagues note that due to the lower magnesia and potash, this fragment fits better with the Syrian-Palestinian glass (Swan *et al.*,2017:112). The task of this thesis was to distinguish which types of glass from Sīrāf were involved in any trade mechanism at a given point in time to the north in the Persian Gulf and the south along the East African coast. It becomes immediately apparent that the Eastern-type glasses from Sīrāf support a maritime trade. But the reason for the absence of the northern Syrian glass in Sīrāf still remains unclear. This will be an interesting future research project.

8.3 Types of Early Islamic glass traded in the Persian Gulf and in Unguja Ukuu

Among the Persian Gulf ports flourishing during the 7th to 11th centuries AD, which were well connected with one another as well as to interior cities and to the wider Indian Ocean, , the port at Baṣra in southern Iraq occupies a special position. In contrast to Sīrāf, its sister port which lies off the Persian coast of the Persian Gulf, Baṣra was in close proximity to Kadhima, Mughaira and Shiqaya, and provides us through chemical analysis results with unparalleled richness and a variety of glass vessels coming from major production zones in the Islamic world. The vessels travelled north as far as Unguja Ukuu on the East African coast. From the two hundred sixty glasses analysed in this thesis, it was obvious that certain types of vessels came to the Persian Gulf and Unguja Ukuu from central places. Common groups of glass were identified at Kadhima, Mughaira, Shiqaya and at Unguja Ukuu. But this was not the case for Sīrāf. There, the absence of common groups of glass was a clear indication that Sīrāf was less likely to have been the key player in glass trade. The glass trade in Baṣra was probably shaped by Baṣra's location, situated far up the Shatt al-Arab river, well connected by the Tigris and Euphrates rivers and by the old caravan routes that gave access to plant ash glass produced in the glass workshops of Syria, Sāmarrā, Ctesiphon and an unknown Iraqi place. Baṣra could supply the sea routes and the East African coast with glasses from Syria, Sāmarrā, Baghdad (Ctesiphon) and unknown Iraqi place. Chemical analysis shows that an extensive glass trade was well established in the Kuwaiti sites and in Unguja Ukuu in the 7th century AD, and that those coastal communities were not static. The sources of glass are an indication that the above communities were well connected through a complex network of exchange (with glass coming from different central places). Evidence of this trade can be found in the chemical composition of the glasses.

This thesis discusses a number of vessel types and their sources that can be useful in studying coastal community interactions, glass production organisation and glass vessels specialisation. To begin with specialisation and the appearance of regional traditions, we will apply Renfrew's theory (Renfrew,1984) of central places, which states that every civilization has central places that are the focus of exchange of goods and information (Wood,2012:37). An increase in exchange/trade maybe leads to organisation and specialisation (Wood,2012:38). Thus, the origins of glasses can be studied through the rise of central places. Through the analysis it was noted that northern Syria, Sāmarrā, Ctesiphon and an unknown Iraqi place had organised the production of glass

and specialised ateliers for the production of vessel types. Restricted vessel types were produced at those central places although other types could also occur. The growth of the central places enabled the development of a permanent centre for social and religious exchange, and with the increasing population the organisation of production and specialisation became necessary. The reasons for standardisation and specialisation still remain unclear. We cannot know whether they were independent (adaptational) or political. A clear example of specialisation was the plant ash scratch-decorated vessels made by Syrian's glassworkers, perhaps in al-Raqqa. This has been suspected for a long time, but was also confirmed by trace element analysis conducted by Henderson and his colleagues and now in this thesis it has been proved again (Henderson *et al.*, 2016). Based on the ratio of MgO:CaO, the analysis shows that plant ash scratch-decorated vessels were also made in Iraq, with the glass and almost certainly the vessels being made in Sāmarrā (Henderson *et al.*,2016:139). Also in contrast to the 'inland' production of scratch decorated vessels from Sāmarrā, Iraq (Henderson *et al.*,2016) Syria (possibly al-Raqqa) and Iran (possibly Nishapur) (Li *et al.*,2016), Kato *et al.* (2009) have shown that scratch decorated vessels were also made with Egyptian (natron) glass. It is therefore clear that while the various styles of scratch decoration might be considered specialised products, the glass used to make the vessels and possibly the vessels themselves were made in a number of centres across the Middle East.

Al-Raqqa, the summer residence of the caliph Harun al-Rashid at the end of the 8th century AD, provides extensive evidence of glass production. This could be the place where the northern Syrian open-stepped rims and the open-triangular beaked rims were fused. Open-stepped rims were also of an unknown Iraqi place, compositionally distinct from the northern Syrian glass. From the closed or semi-open vessel types, we recognised Syrian specialisation in the closed and semi-open flaring straight vessels. Closed and semi-open flaring straight vessels were also a specialisation of an unknown Iraqi place, compositionally distinct from the northern Syrian glass. Glassworkers at this unknown Iraqi place specialised also in the production of closed and semi-open closed and flattened rims and in closed ribbed necks. Through chemical analysis it was noted that Sāmarrā, the ´Abbāsid capital between AD 836 and 892 , had closer trading relations with Unguja Ukuu, in comparison with the Kuwaiti sites that had closer connections with Ctesiphon. Sāmarrā turned out to be the place of production of the 'ice-blue' (pale blue, almost colourless, with no green hue) glass used to fuse vessels with relatively plain, slightly thickened and rounded types of rim. It is especially interesting to observe the high standardisation of colour; every plain-rounded rim in Unguja Ukuu was produced with 'ice-blue' glass from Sāmarrā. The above vessels, dated probably to the 9th century AD, belong to the most common group at

Unguja Ukuu and were associated with a variety of functions, perhaps for eating, drinking or display (Blair,2016:107). The presence of plain rounded rims of 'ice-blue' glass from Sāmarrā was rare at the Persian Gulf sites of Kadhima, Mughaira and Shiqaya. The assumption of the existence of a secondary workshop in Sāmarrā is further supported by an 'ice-blue' pinched decorated fragment that belongs to the same group. Previous chemical analysis conducted by Henderson and his colleagues shows that a pinched decorated bowl, together with four pale green mould-decorated vessels, now in the Museum for Islamic Art in Berlin, were probably made in Sāmarrā's workshops. On the basis of alumina and lime concentrations, it cannot be stated whether a trailed decorated vessel is more likely to be from Sāmarrā. Judging from chemical analysis results, it was noted that Baghdad's (Ctesiphon) workshops specialised in the production of the closed ribbed necks and in closed plain vertical vessels.

The majority of natron glasses uncovered in Unguja Ukuu and in the Kuwaiti sites were probably made in the eastern Mediterranean and fit the oxide profile for Levantine I glasses. However this is not the case for HIMT or WHIMT glasses which are thought to have been made in Egypt (Conte *et al.*,2015). Nine samples with ***Levantine I*** compositions were identified in Unguja Ukuu and two in the Kuwaiti sites. All the ***Levantine I*** glasses uncovered at Unguja Ukuu were from pinch-decorated vessels so this was evidently another specialisation of the Levantine region. It should also, however, be noted that pinch-decorated glasses were also made with plant ash. Some, for example, were made in Iraq (Henderson *et al.*,2016). The only examples of Egyptian glass of the ***Egyptian II*** composition identified in Unguja Ukuu were two pushed up bases and a ribbed neck. Levantine natron glasses were also used to make Unguja Ukuu pushed-in and applied bases, a vessel with a ribbed neck (8th century AD), a closed vessel with a rolled in rim, two plain rounded rims and three lug handles. None of the glass vessels analysed contain the elevated alumina levels (c. 7-13%) found in glass beads from Unguja Ukuu (Wood *et al.*,2016) referred to as 'mineral-soda-alumina' (Dussubieux *et al.*,2010) and resulting from Indian ocean contacts. Moreover, there are no indications of a central Asian origin for the glass - none contain 4% or more K_2O, an indication of such an origin, as pointed out by Brill (1972 and 2001) and Vahidzadeh and Afrund (2010).

8.4 Suggestions for future work

Two hundred and sixty glasses from Kadhima, Mughaira, Shiqaya and Unguja Ukuu have been analysed by EPMA and SEM. Four groups were identified. Ultimately, the output of EPMA and SEM was the chemical characterisation of the glasses uncovered in Kadhima, Mughaira, Shiqaya and Unguja Ukuu. The majority are made of glass produced in well-known regions of the Islamic world. Two groups, having discrete compositional characteristics in terms of their major element compositions, have never been identified before. According to its productivity in terms of results, this thesis achieved its objectives relating to the sources of 7th to 11th century AD glass and trade in the Persian Gulf and in Unguja Ukuu on the East African coast. It is worth reiterating that this thesis generated a huge amount of knowledge in a relatively short period. However, it was not able to make an explicit statement about whether Baṣra was related with the two unknown sources that were identified here, designated as ***Group III*** and ***Group IV***. Much work remains to be done. Isotopic analysis of the Kuwaiti and Unguja Ukuu glasses has huge potential to enhance the value of the results of this thesis.

The next stage after major chemical analysis of this thesis would be to locate and test samples from several centres east of Euphrates and up the Tigris to investigate the provenance of ***Group III*** related with an unknown Iraqi source (Henderson *et al.*,2005;Degryse *et al.*,2010). Major and trace element analysis may therefore be useful to identify the source of plant ash glasses, but new approaches may also be needed (Henderson *et al.*,2005;Degryse *et al.*,2010:83). The isotopes of strontium and neodymium may be particular useful in the investigation of glasses made using plant ash as the main source of flux, to identify the provenance of primary glass production (Henderson *et al.*,2005;Degryse *et al.*,2010:83). $^{87}Sr/^{86}Sr$ isotope ratio of the glass reflects that of the plant ash which was in itself derived from the bio-available Sr in the soil where the plant grew (likely to reflect the local geology) and the isotopes of Nd are particularly useful indicators of the origin of glass, because glassmaking sands from the eastern Mediterranean coast carry a distinctive signature related to their derivation from the Nile (Henderson,2005;Degryse *et al.*, 2010). In Sr-Nd isotopic analysis, we could identify the sand that the plant ash ***Group III*** glass was made from and the plant ash used. It is noted that there is always the possibility that a production centre used ashes of plants from different locations (Henderson,2005;Degryse *et al.*, 2010).

Glass compositional data studied in this thesis, in order to supplement historical and archaeological investigations of glass production and exchange, show that a limited range of rim types uncovered in Kadhima, Mughaira, Shiqaya and Unguja Ukuu came from specific broad geographic glass production zones. Work needs to be done at more sites east of Euphrates and across the Tigris River and also on the East African coast. By expanding the typology including material from more sites and a wider region, it will be possible to broaden the picture. Chemically analysed samples divided into specific open, closed and semi-open vessels can help to determine whether the identified types uncovered at different sites were from the same production zones. The author's proposal that certain types were made at certain places can be tested, and we will see whether the same model can apply to different sites. The fact that this model can apply to assemblages from Kuwait and Unguja Ukuu in spite of their various geographic, cultural and socio-economic differences, does not mean that it will apply to other sites across Euphrates, Tigris and the East African coast. This model does not apply even in Sīrāf, which is in close proximity to Kuwait and with close exchange relations with both sites.

Finally, a great deal remains to be done with the 9th century AD 'ice-blue' plain rounded rims produced in Sāmarrā, very common at Unguja Ukuu and rare in Kuwait (a single sample uncovered from 9th century AD layers in Shiqaya). This thesis has shown that during the 9th century AD, Sāmarrā's glassworkers specialised in the fusion of relatively plain, slightly thickened and rounded rims using 'ice-blue' glass, and in their decoration, particularly according to the pinched technique of tooling. In the domain of plain rims (rounded) coming from Sāmarrā, it was interesting to explore whether the single fragment from the Kuwaiti site could have come from Sāmarrā. While it was expected that the 'ice blue' fragment came from Sāmarrā, it turned out to come from the unknown source. Attention has to be drawn to the following conclusion: in the atelier/ateliers at Sāmarrā and an unknown place, there was a preference to work plain rims (rounded) only from 'ice-blue' glass. A study of more 'ice-blue' plain rounded rims could show whether workshops outside of Sāmarrā imitate the high standards of the decoration. Significant progress in this area of glass production and trade in the Persian Gulf has been achieved and more may be expected over the next few years.

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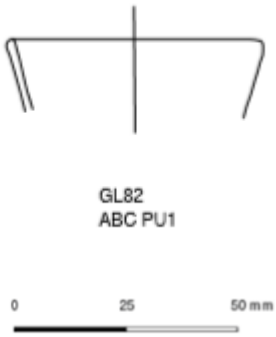
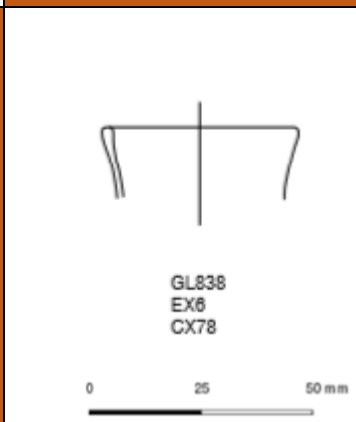
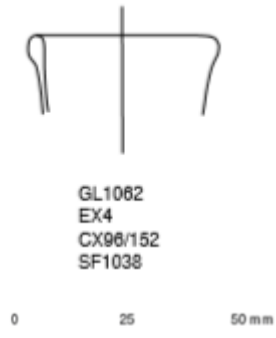
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Preservation of the RGZM and the Shaanxi Provincial Institute of Archaeology, December, 11th-12th, 2008, Verlag des Rômisch-Germanishen Zentralmuseums, Mainz.

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

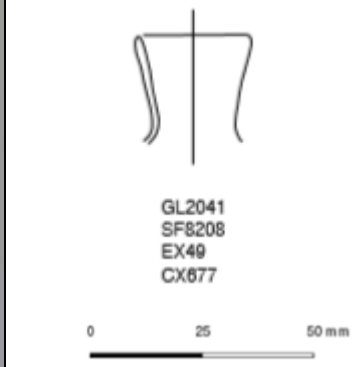
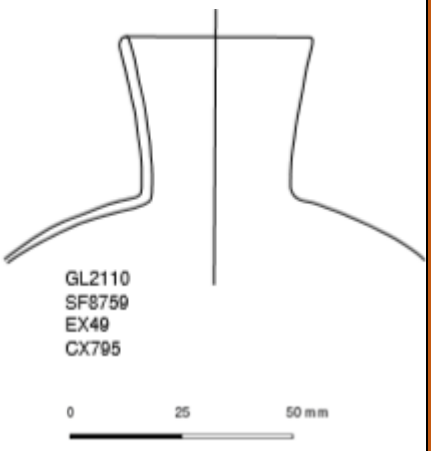
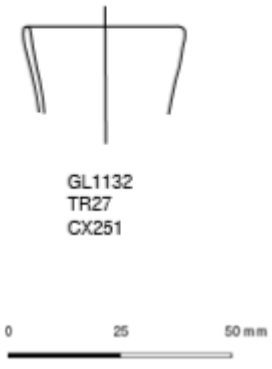
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

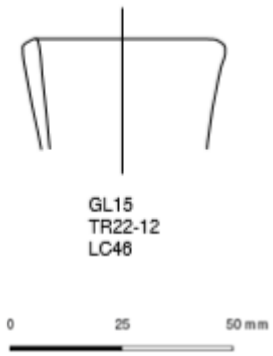
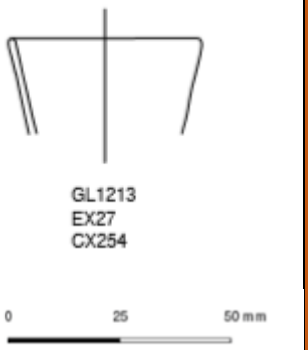
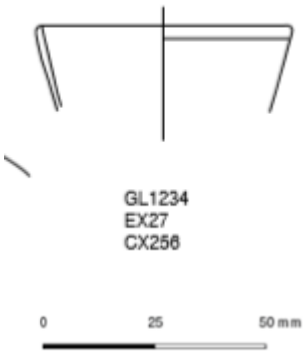
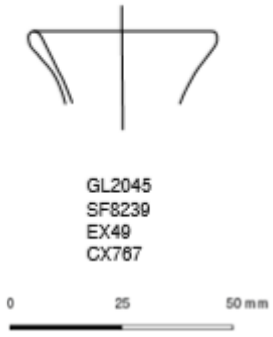
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

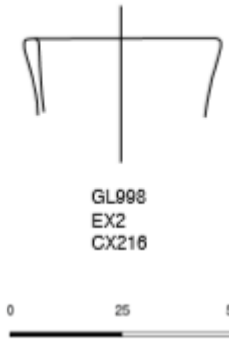
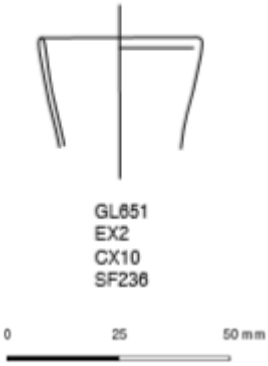
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

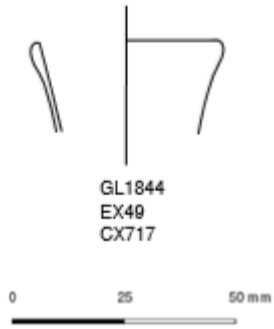
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

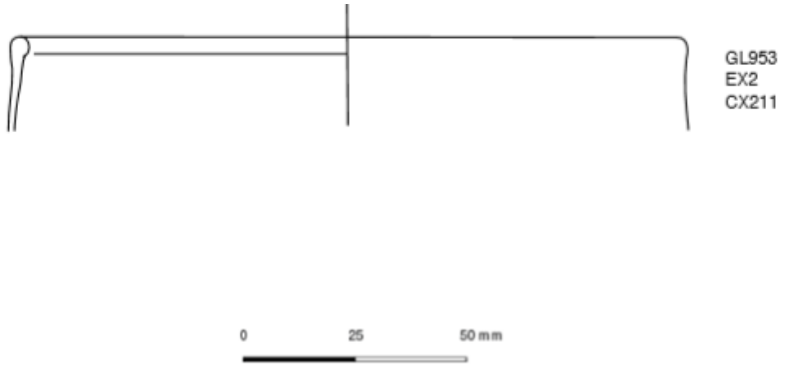
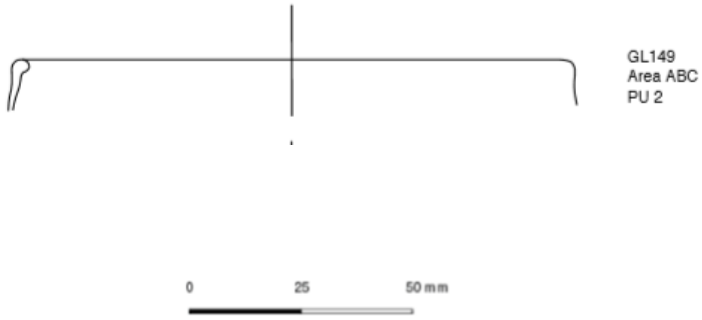
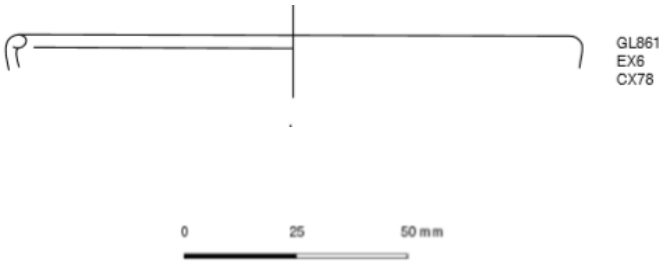
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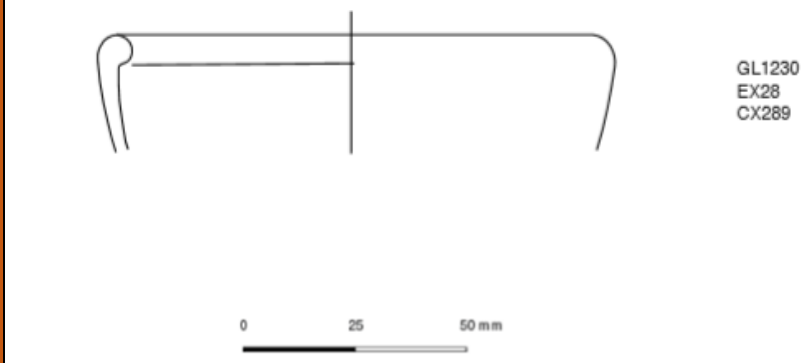
Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD (Blair, 2016).

Rolled-in rims	
	
	
	

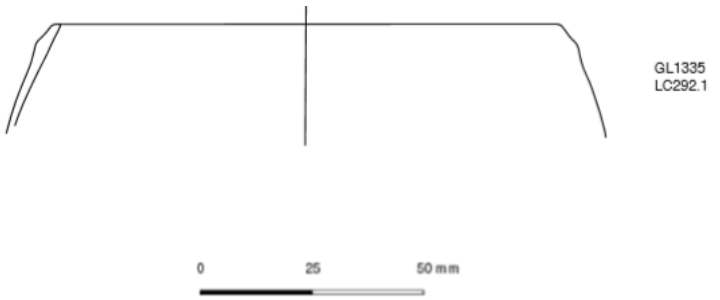
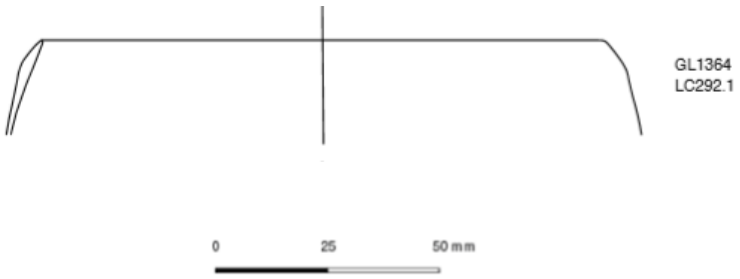
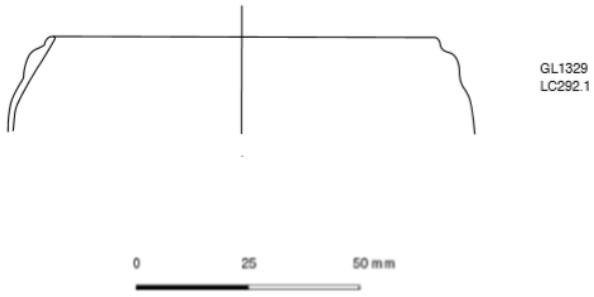
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SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

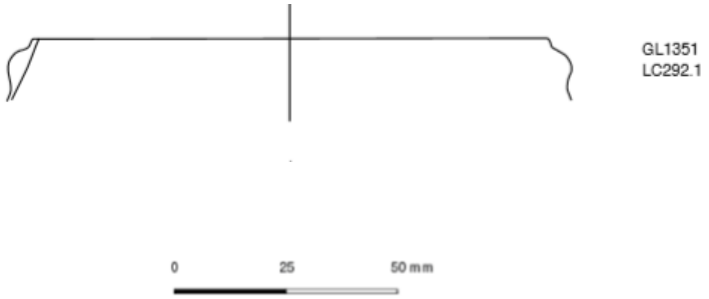
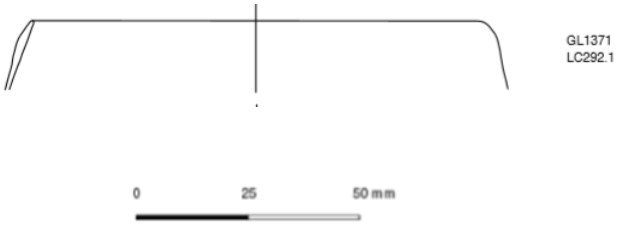
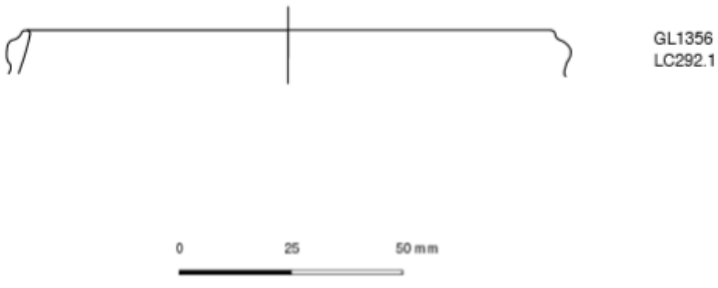
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Stepped rims	
	
	
	

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

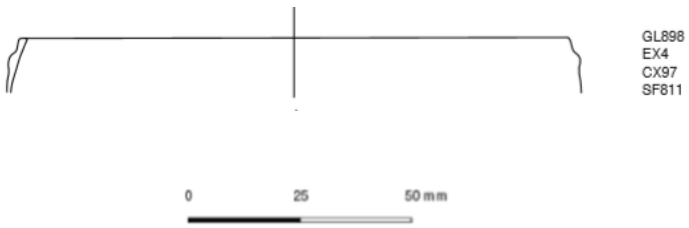
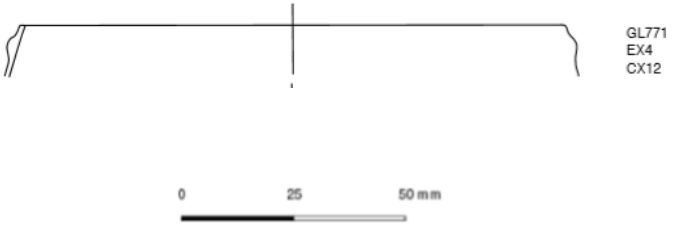
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Stepped rims	
	
	
	

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

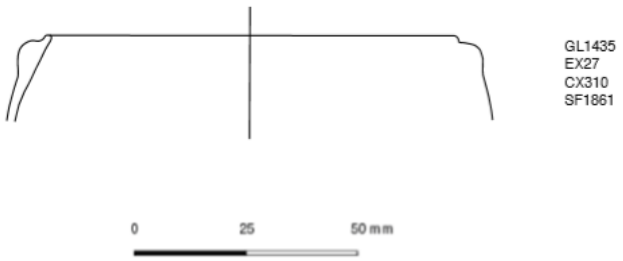
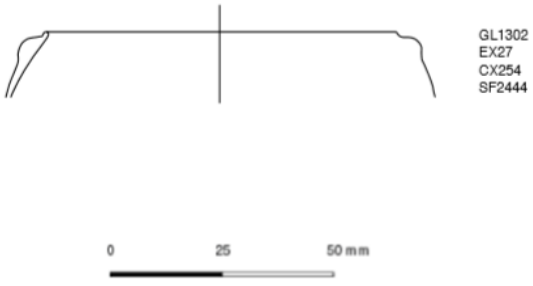
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Stepped rims	
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

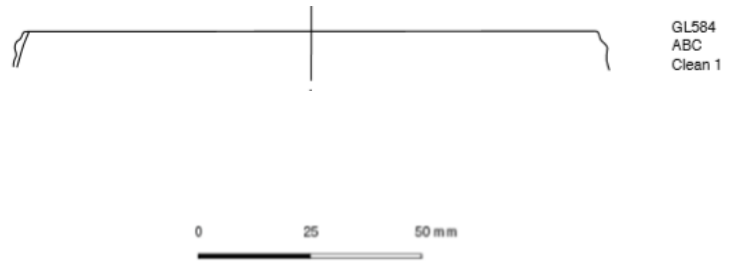
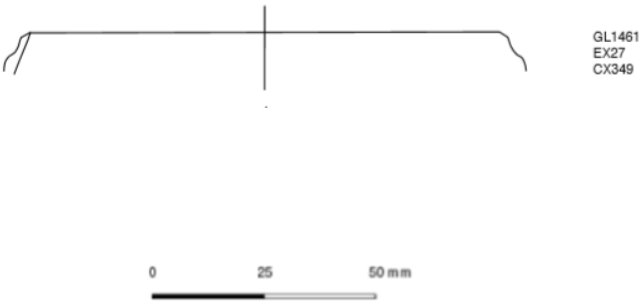
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Stepped rims	
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

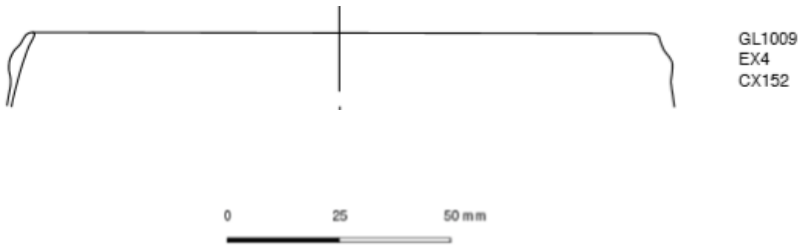
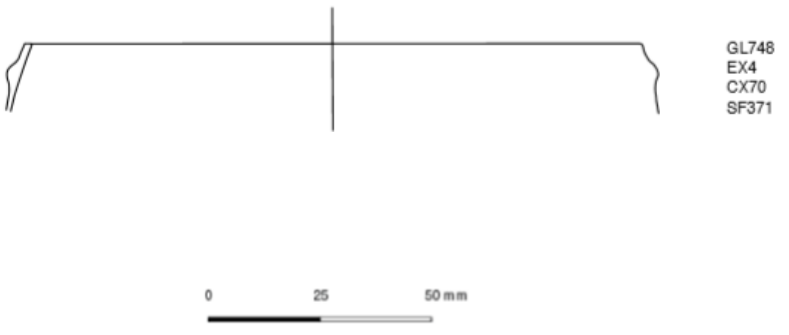
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Stepped rims	
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Stepped rims	
	
	No available drawing GL007
	

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

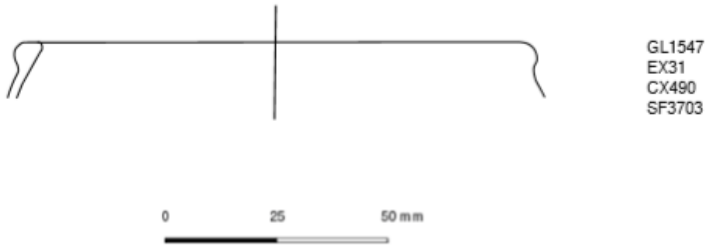
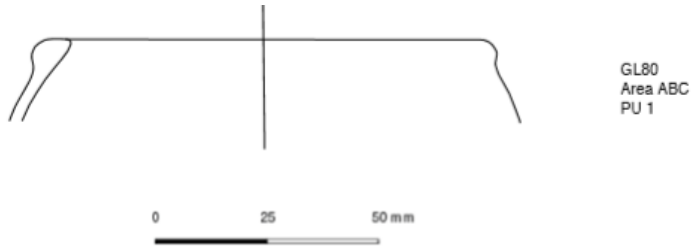
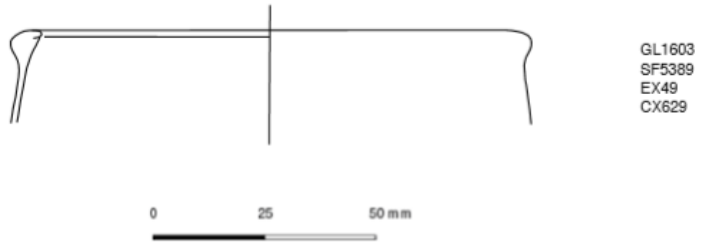
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SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

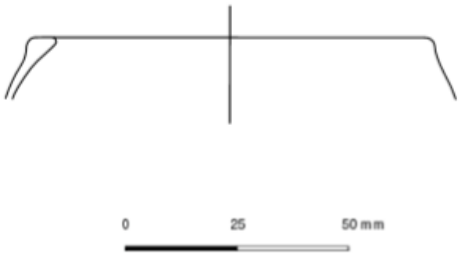
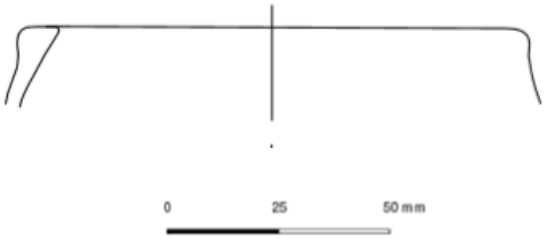
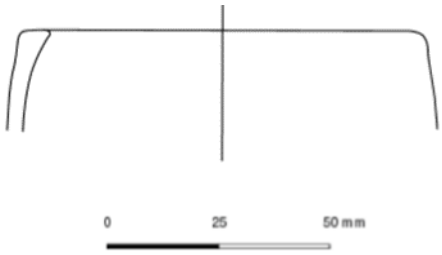
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Triangular-beaked rims	
	
	
	

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA. SHIQAYA

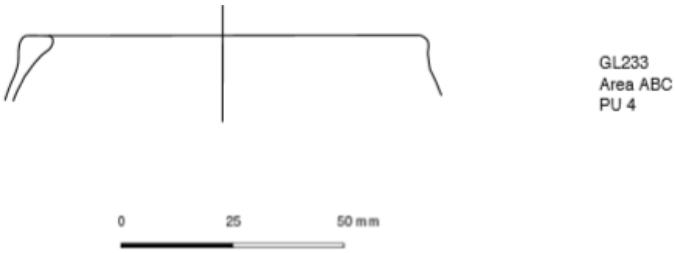
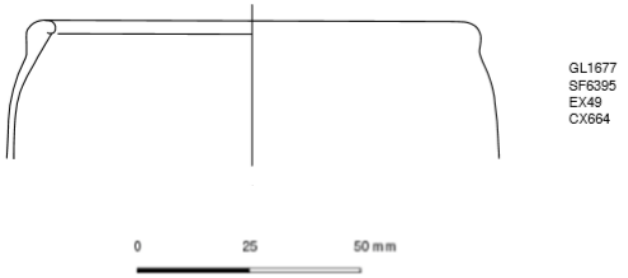
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Triangular-beaked rims	
	 GL236 ABC PU 4
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	 GL14 TR22-12 LC46

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

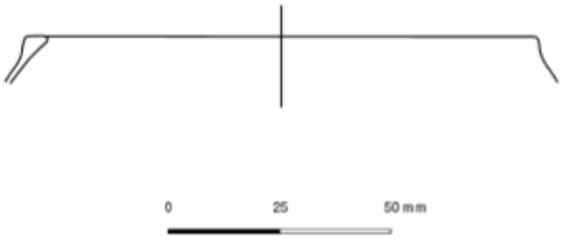
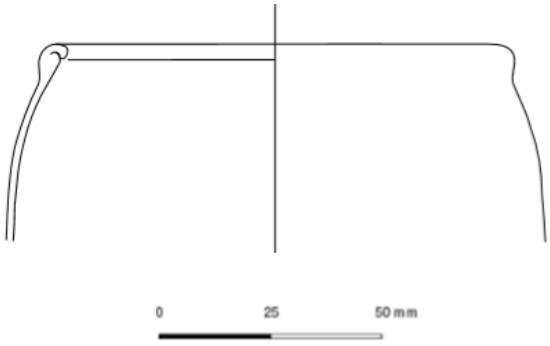
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SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

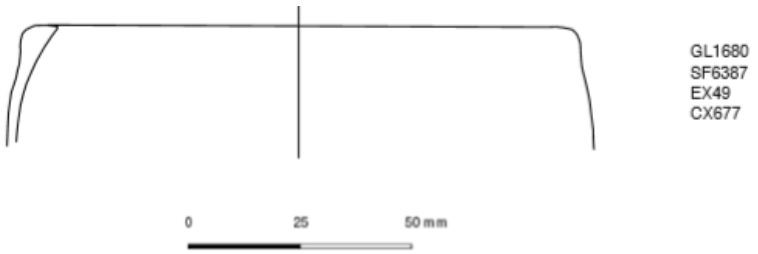
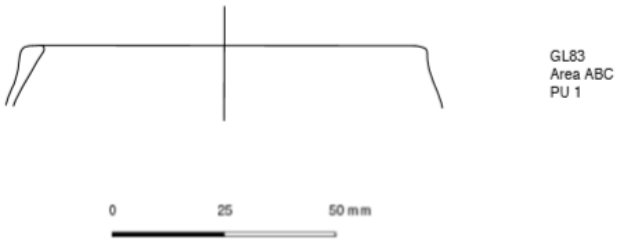
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Triangular-beaked rims	
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	 GL234 ABC PU 4
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA,SHIQAYA

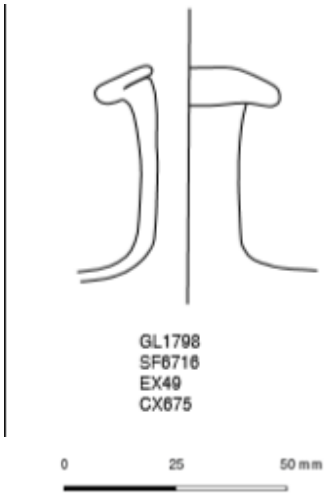
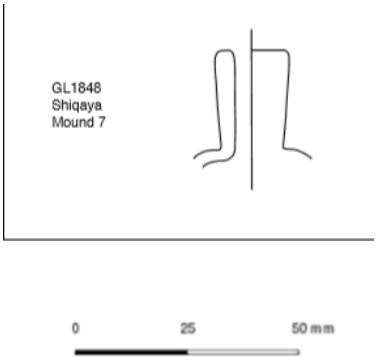
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Triangular-beaked rims	
	
	

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA,SHIQAYA

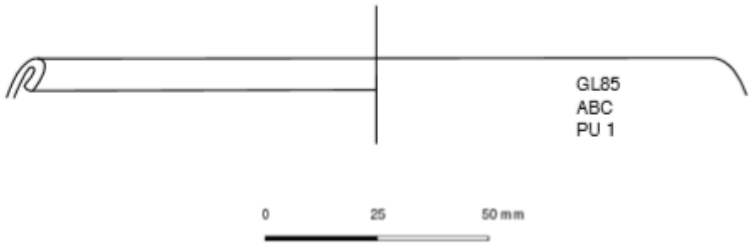
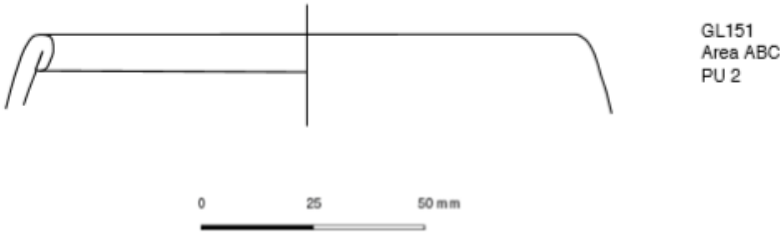
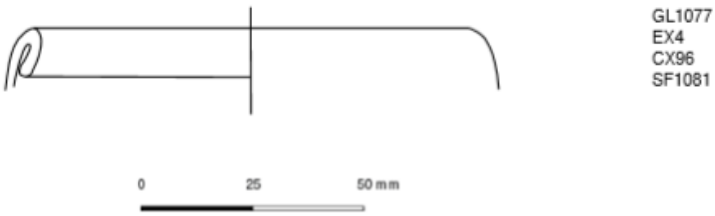
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Bottles and plain rounded rims		
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

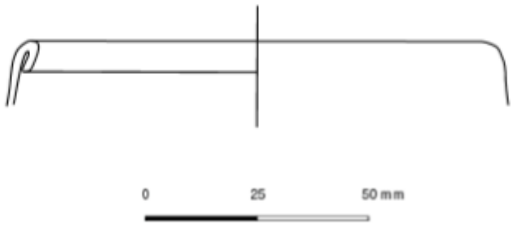
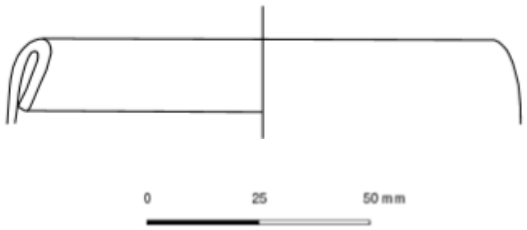
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open inwards-folded rims	
	
	
	

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

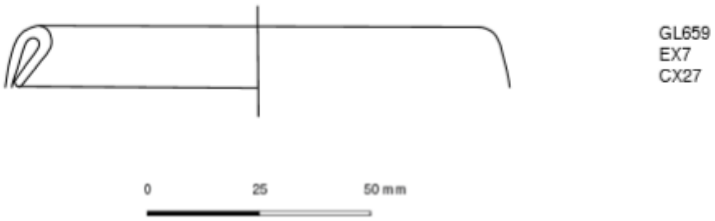
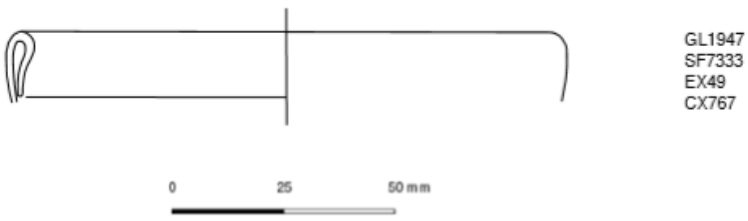
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open inwards-folded rims	
	 GL7 TR21-8 LC19
	No available drawing GL534
	 GL1556 EX40 CX497 SF3799

Appendix 1

SAMPLE IMAGES/KADHIMA. MUGHAIRA, SHIQAYA

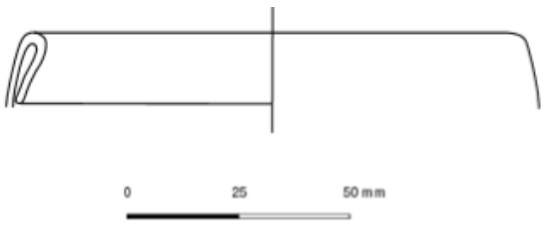
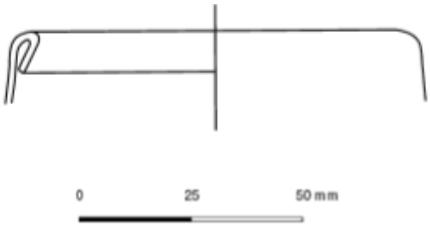
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open inwards-folded rims	
	No available drawing GL639
	
	

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

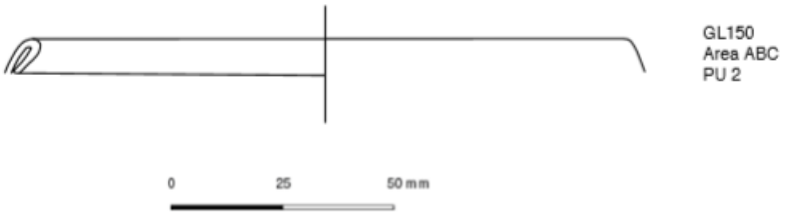
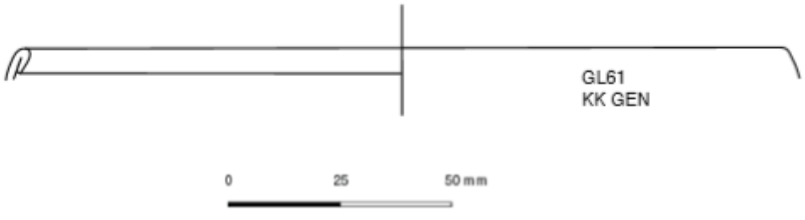
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open inwards-folded rims	
	No available drawing GL1786
	 GL152 Area ABC PU 2
	 GL269 Area ABC PU 6

Appendix 1

SAMPLE IMAGES/KADHIMA. MUGHAIRA. SHIQAYA

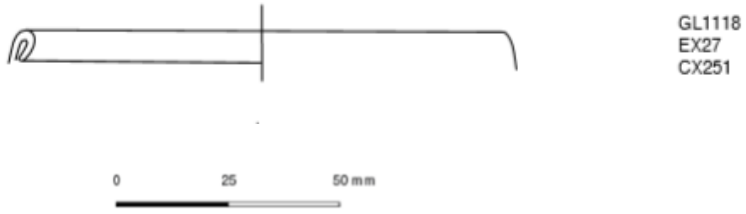
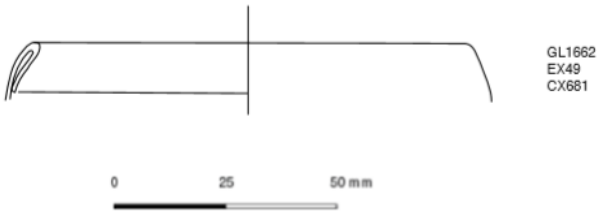
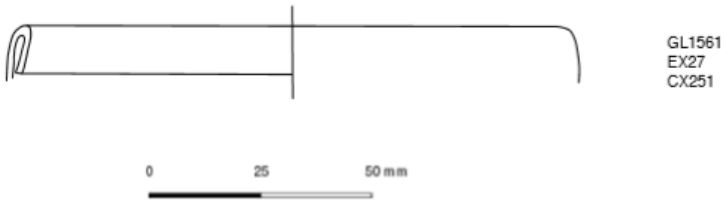
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

<table>
<tr><td colspan="2">Open inwards-folded rims</td></tr>
<tr><td>
</td><td>No available drawing GL1239</td></tr>
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

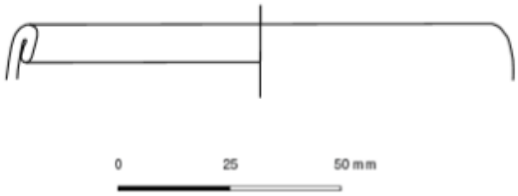
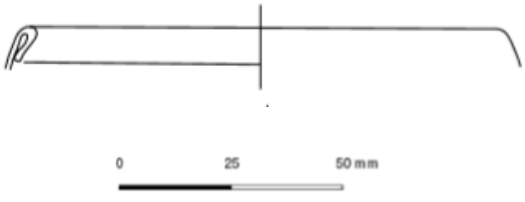
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open inwards-folded rims	
	
	
	

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

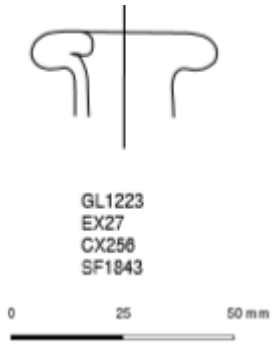
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open inwards-folded rims	
	No available drawing GL634
	 GL1024 LC234
	 GL1808 EX49 CX629/631

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

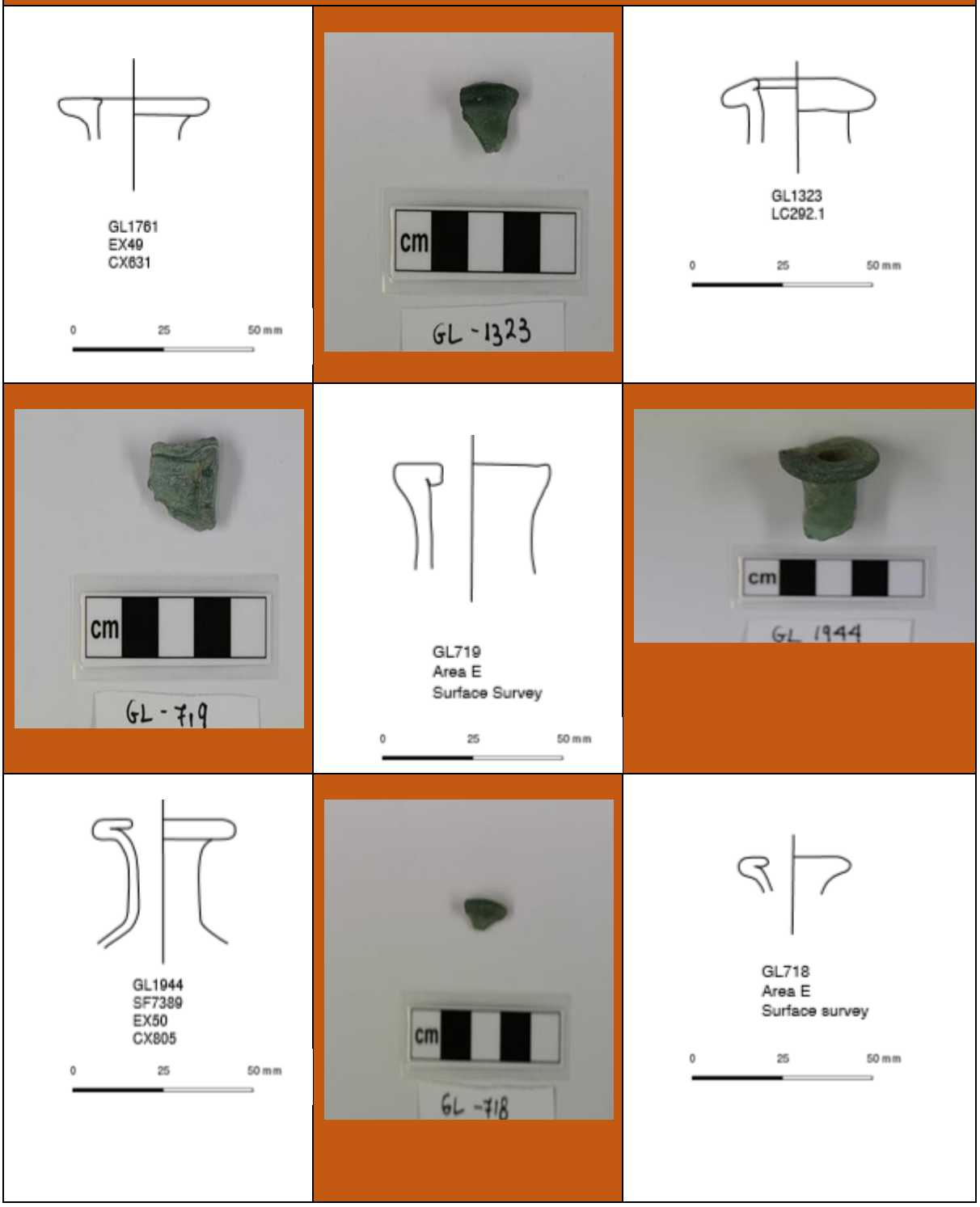
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<td>No available drawing GL81</td>
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<td>No available drawing GL361</td>
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Closed folded and flattened rims



Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Closed folded and flattened rims





GL1599
SF5353
EX49
CX629

0 25 50 mm





GL725
EX4
CX12

0 25 50 mm

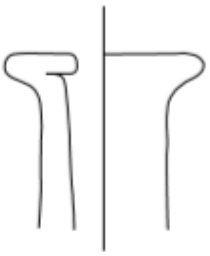




GL986
EX4
CX21
SF979

0 25 50 mm





GL2068
SF8549
EX49
CX783

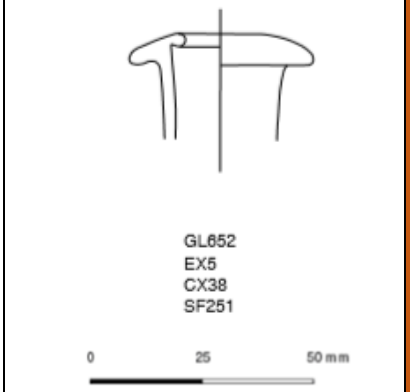
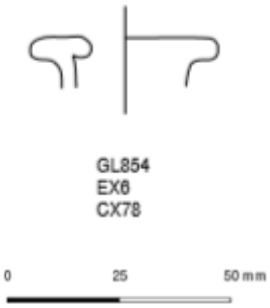
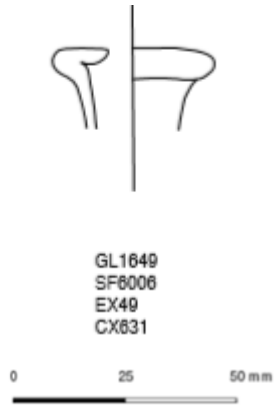
0 25 50 mm



Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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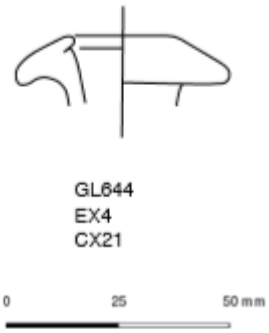
Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Closed folded and flattened rims

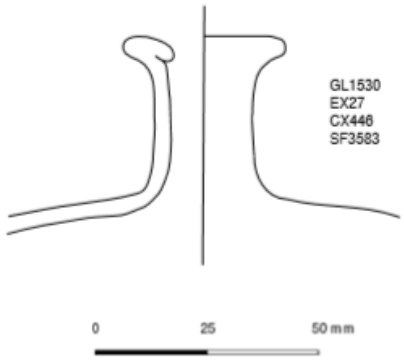








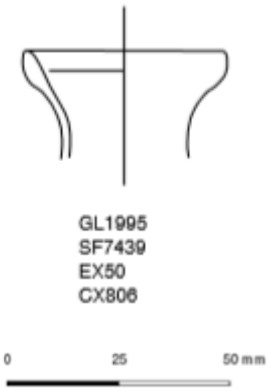
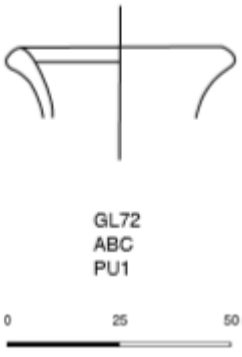




Appendix 1

SAMPLE IMAGES/KAHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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<tr><th colspan="3">Closed flaring necks (rolled-in rims)</th></tr>
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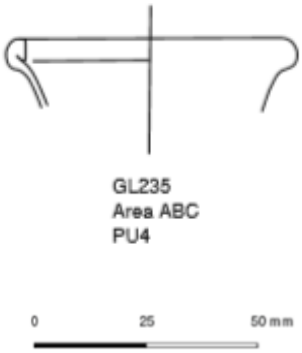
Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA. SHIQAYA

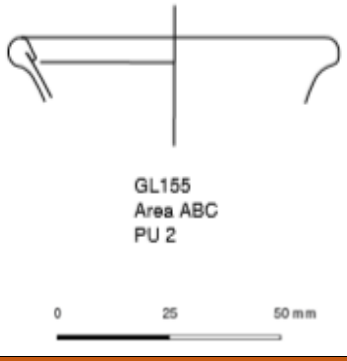
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Closed flaring necks (rolled-in rims)









Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Closed ribbed necks (narrow)



GL1264



GL1264
EX27
CX254
SF2194

0 25 50 mm





GL1308
LC292.1

0 25 50 mm





GL1269
EX27
CX256
SF3009

0 25 50 mm





GL692 & GL897
EX4
CX37 & CX118
SF199 & SF810

0 25 50 mm



Appendix 1

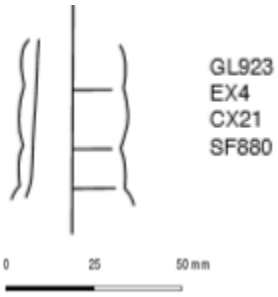
SAMPLE IMAGES/KDHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Closed ribbed necks (narrow)



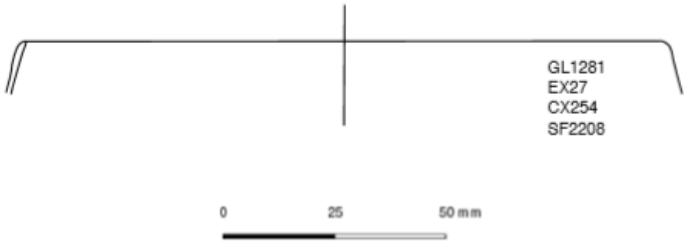




Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA. SHIQAYA

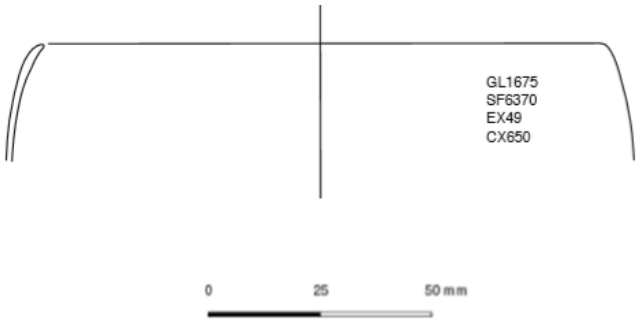
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open plain rims (fine)	
	No available drawing GL232
	
	No available drawing GL1003

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open plain rims (fine)	
	No available drawing GL1616
	No available drawing GL640
	

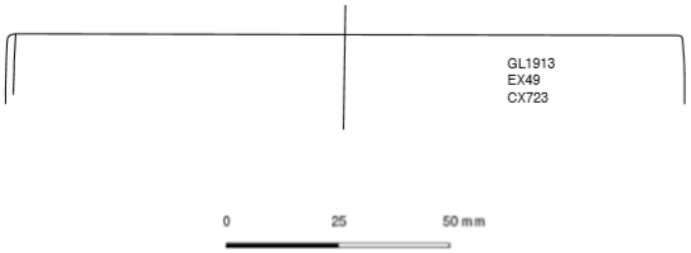
Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open plain rims (fine)



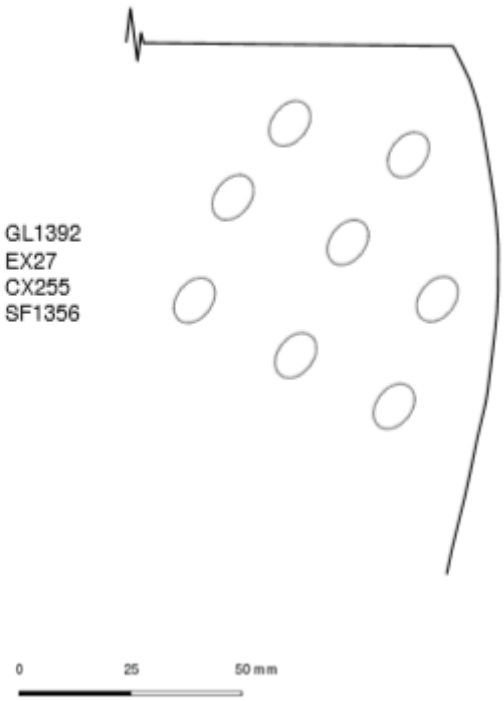


Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

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Open plain rim (fine)</td><td>
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<tr><td>

Push-up base</td><td>No available drawing GL1393</td></tr>
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

ABC vessels		
 Open plain (fine)	No available drawing GL1394	 Open plain (fine)
No available drawing GL1395	 Open plain (fine)	No available drawing GL1396
 Open plain (fine)	No available drawing GL1397	 Open plain (fine)

Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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GL1399</td></tr>
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Open plain (fine)</td><td>No available drawing
GL1400</td><td>

Open plain (fine)</td></tr>
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GL1401</td><td colspan="2"></td></tr>
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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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GL1402</td><td>

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GL1403</td><td>No available photo GL1404
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GL1404</td></tr>
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GL1405</td><td>

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Appendix 1

SAMPLE IMAGES

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

ABC vessels		
No available drawing GL1406	 Open plain (fine)	No available drawing GL1407
 Open plain (fine)	No available drawing GL1408	 Open plain (fine)
No available drawing GL1409	 Open plain (fine)	No available drawing GL1410

Appendix 1

SAMPLE IMAGES

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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GL1411</td><td>

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GL1412</td><td>

Open plain (fine)</td><td>No available drawing
GL1413</td></tr>
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GL1414</td><td>

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Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

ABC vessels		
No available drawing GL1415	 Open plain (fine)	No available drawing GL1416
 Open plain (fine)	No available drawing GL1417	 Open plain (fine)
No available drawing GL1418	 Open plain (fine)	No available drawing GL1419

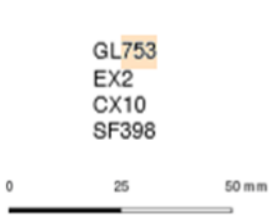
Appendix 1

SAMPLE IMAGES/KADHIMA, MUGHAIRA, SHIQAYA

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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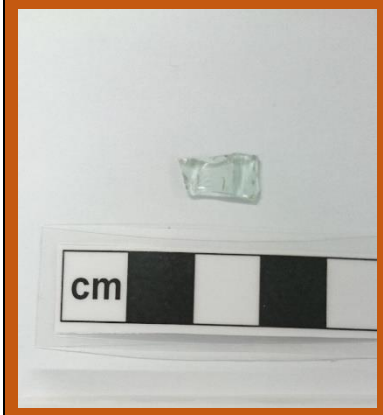
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Undiagnostic</td><td></td><td>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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GL0765</td></tr>
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GL0715</td><td>
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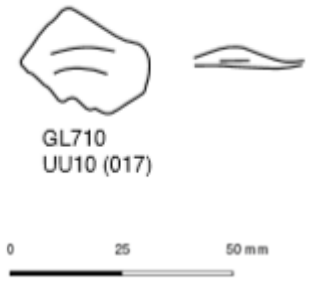
GL1999</td><td>
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GL0710</td></tr>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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GL2933</td>
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GL1855</td>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

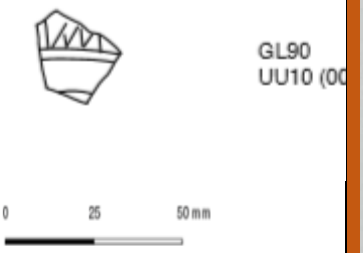
Pinched (decoration)	
 GL0712	No available drawing GL0712

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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GL0090</td><td>
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GL2244</td></tr>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

<table>
<tr><th colspan="3">Trailed and applied (decoration)</th></tr>
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GL3461</td><td>No available drawing
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GL3257</td></tr>
<tr><td>No available drawing
GL3257</td><td>

GL3306</td><td>
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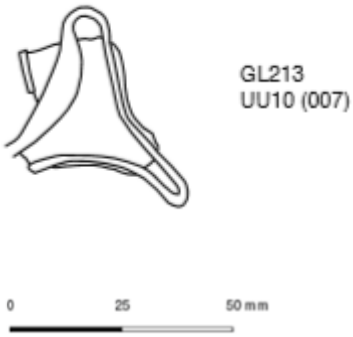
GL201</td><td>
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GL0213</td></tr>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

<table>
<tr><td colspan="3">Trailed and applied (decoration)</td></tr>
<tr><td>
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GL2975</td><td>
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<tr><td colspan="3">Mosaic (decoration)</td></tr>
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GL3145</td><td colspan="2">No available drawing GL3145</td></tr>
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Appendix 1

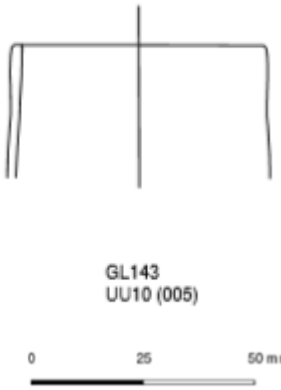
SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Vertical neck-wide

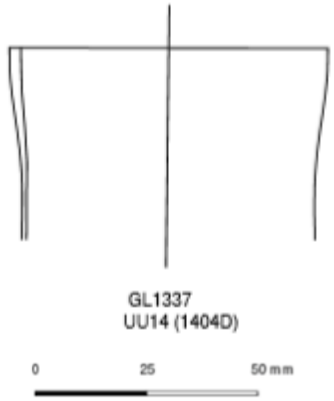


GL0143



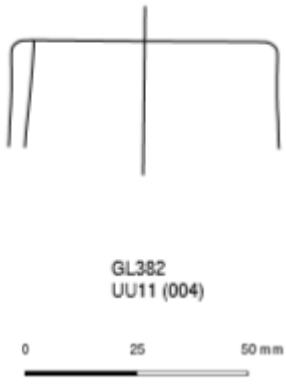


GL1337





GL382



Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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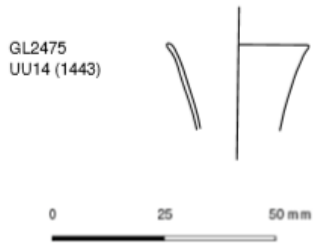
GL572</td><td>No available drawing GL572</td></tr>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

<table>
<tr><th colspan="3">Closed flaring-straight</th></tr>
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GL2475</td>
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GL2689</td>
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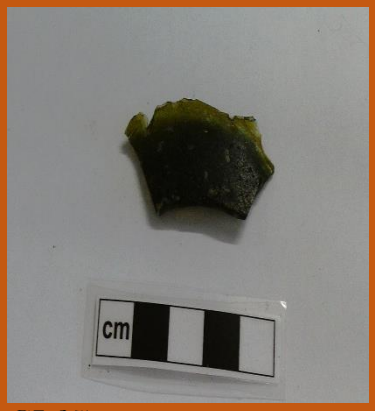
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</tr>
<tr>
<td>

GL3255</td>
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GL3255</td>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

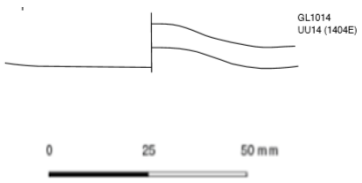
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

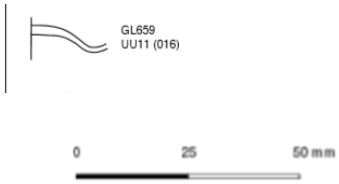
Push-up bases		
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No available drawing GL2293	 GL1633	No available drawing GL1633
 GL0077	No available drawing GL0077	 GL2715

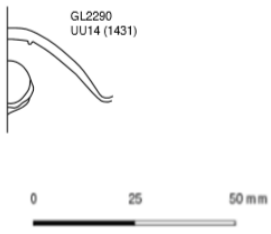
Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

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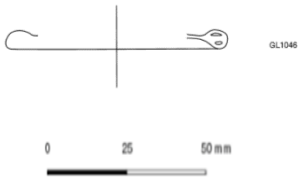
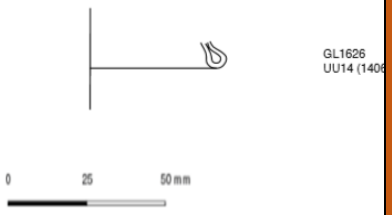
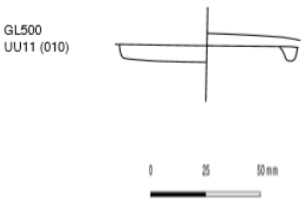
GL659</td><td>
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GL2290</td></tr>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

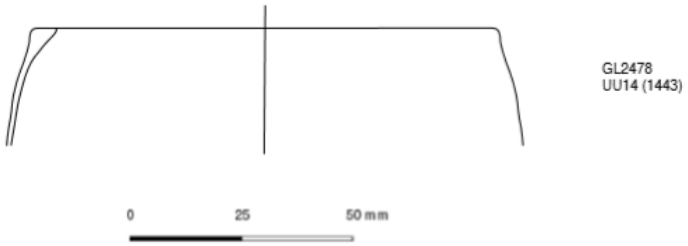
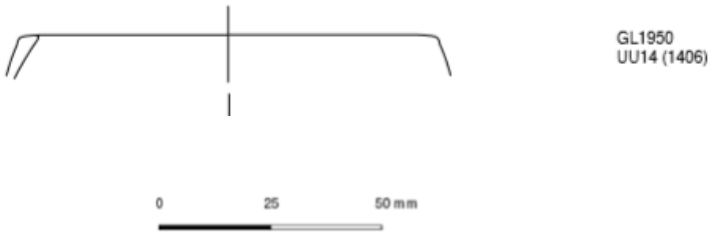
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Ring bases and applied bases		
 GL1046		 GL1626
	 GL1044	No available drawing GL1044
 GL0500		

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

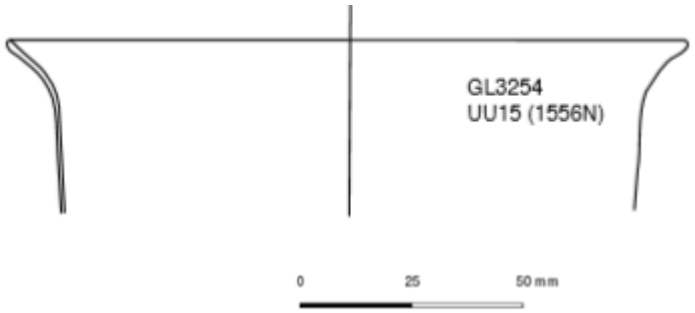
Triangular-beaked rims	
 GL2478	
 GL1950	
 GL2981	No available drawing GL2981

Appendix 1

SAMPLE IMAGES

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

<table>
<tr><th colspan="2">Splayed rims and rolled-in rims</th></tr>
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GL3254</td><td>
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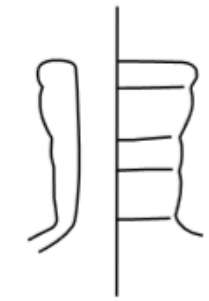
G2616</td><td>No available drawing GL2616</td></tr>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

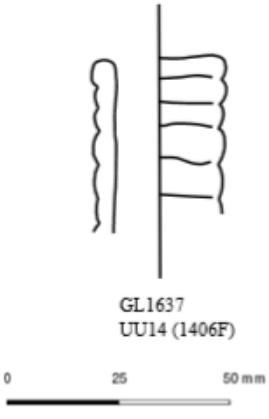
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

<table>
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GL2657</td>
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GL0949</td>
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GL0949</td>
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GL1638</td>
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GL1637</td>
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

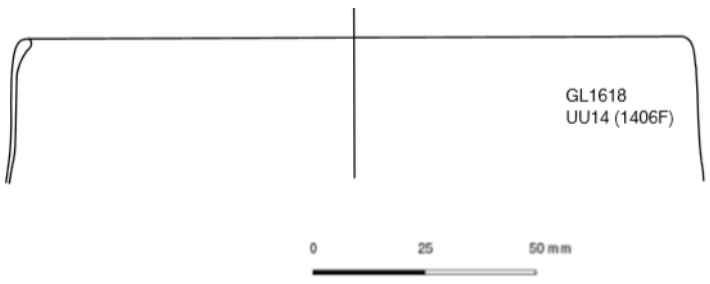
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open plain rims (fine)	
 GL1750	No available drawing GL1750
 GL2522	No available drawing GL2522
 GL2403	No available drawing GL2403

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

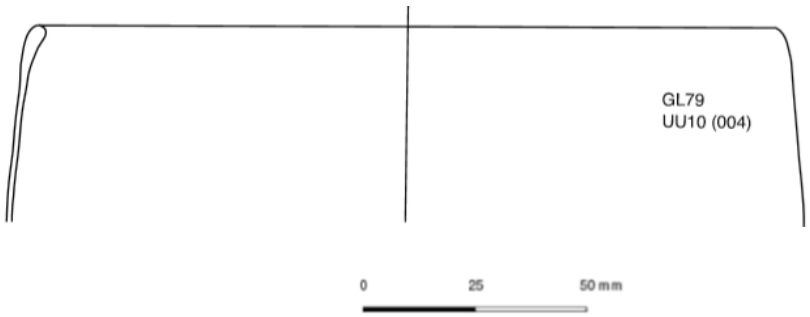
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open plain rims (rounded)	
No available photo GL119	No available drawing GL119
GL2723 	
GL1618 	

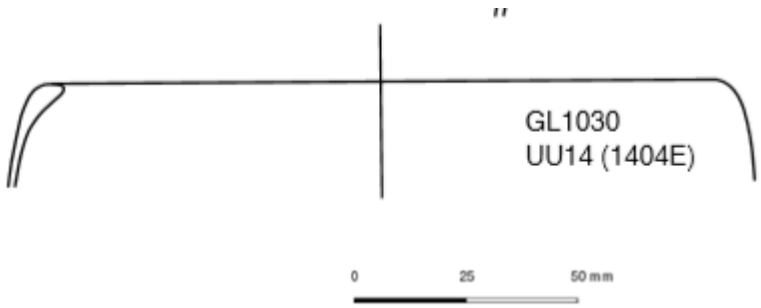
Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

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GL0079</td><td>
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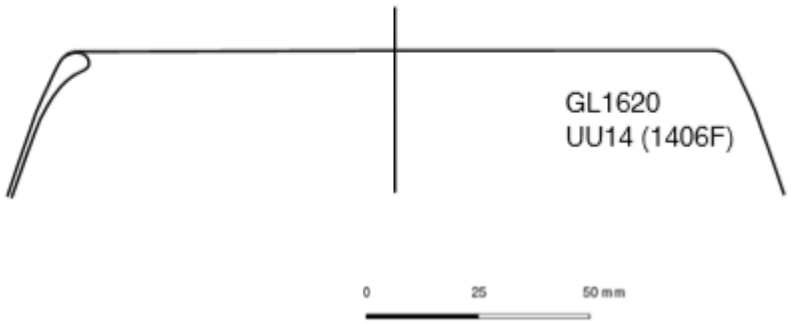
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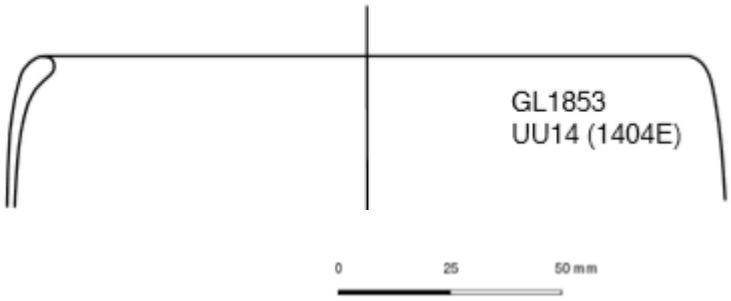
Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

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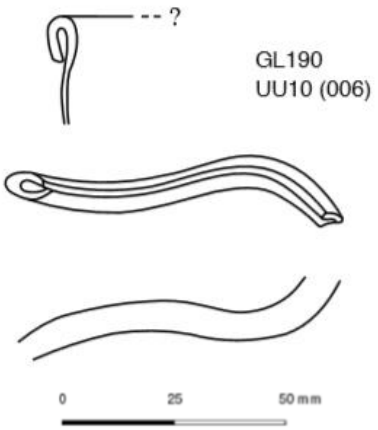
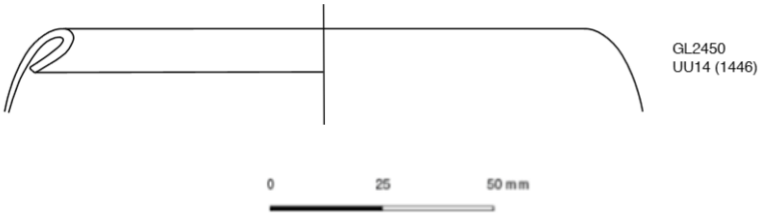
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

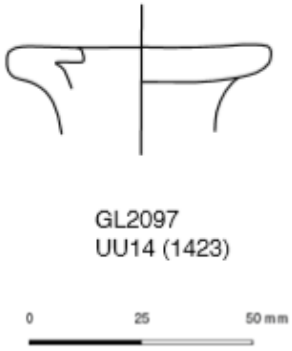
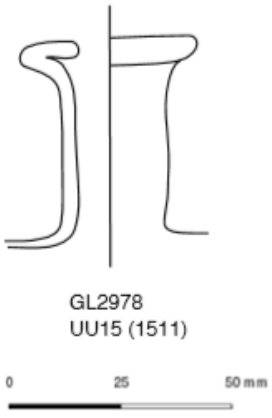
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Open inwards-folded rims	
GL0190 	
GL2450 	

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

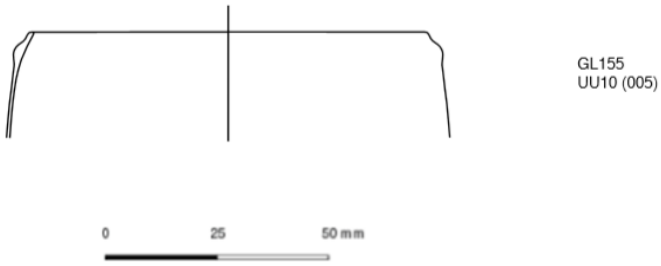
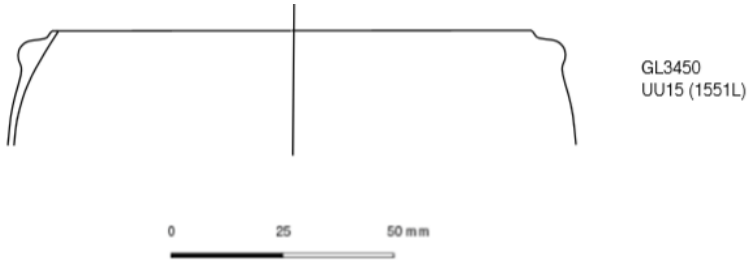
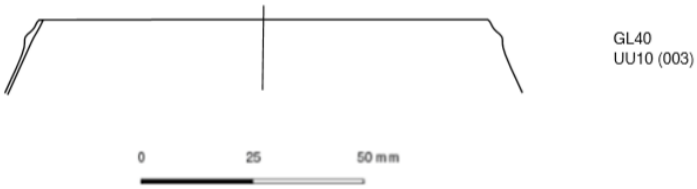
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Folded and flattened rims	
GL2097 	
GL1339 	
GL2978 	

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

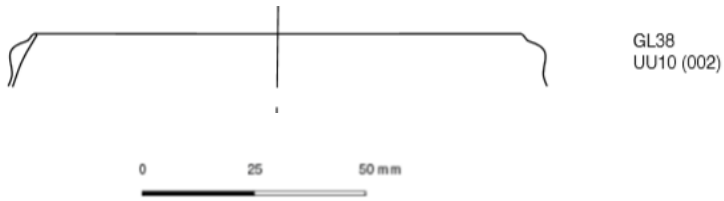
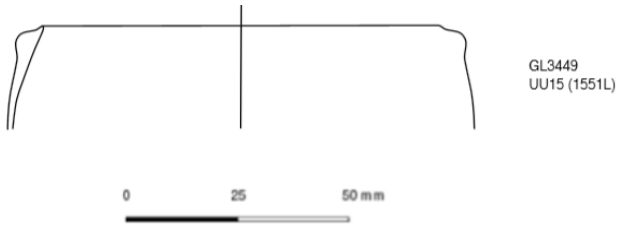
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Stepped rims	
GL0155 	
GL3450 	
GL0040 	

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

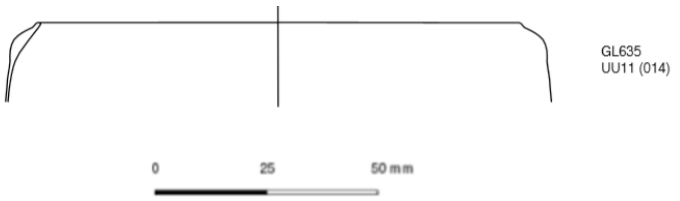
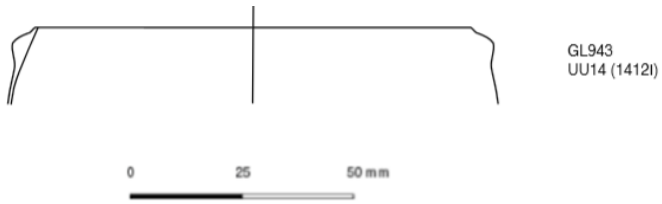
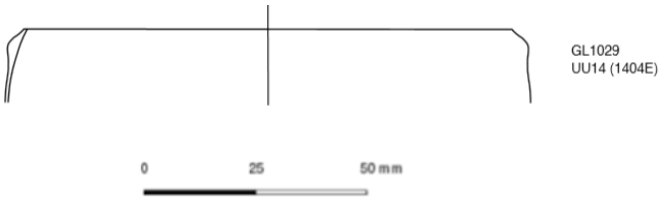
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Stepped rims	
GL0154 	No available drawing GL0154
GL0038 	
GL3449 	

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

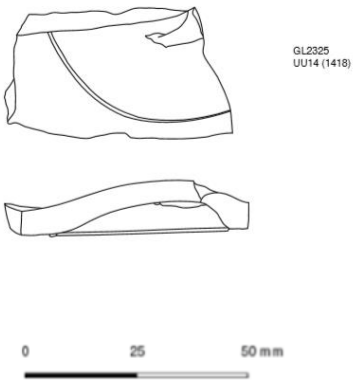
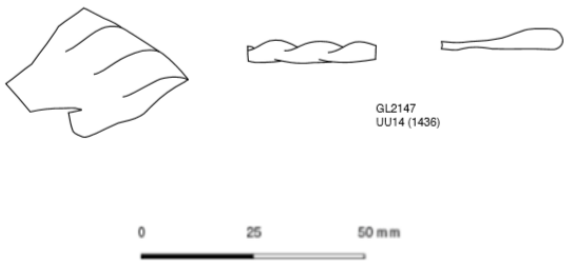
Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Stepped rims	
GL0635 	
GL0943 	
GL1029 	

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Plate	
GL2677 	No available drawing GL2677
GL2325 	
GL2147 	

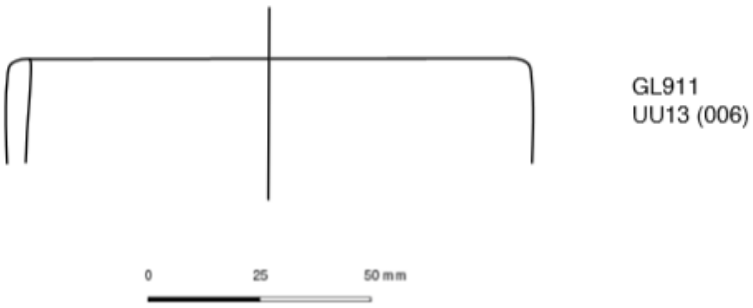
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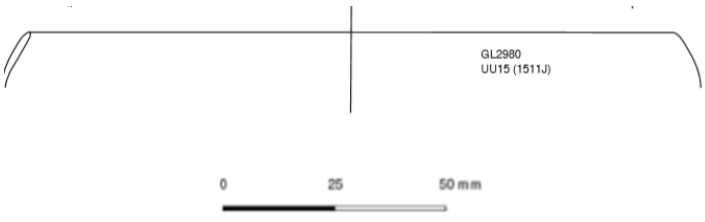
SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

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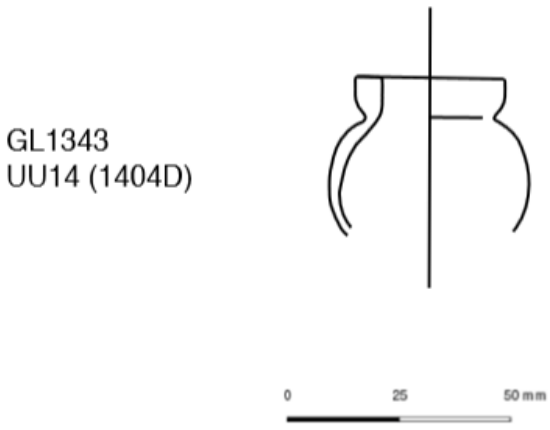
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Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

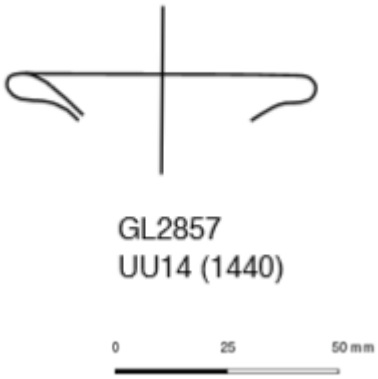
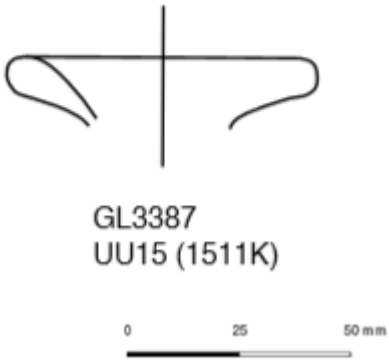
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No available photo</td><td>No available drawing GL2580</td></tr>
<tr><td colspan="2">Miniature jar</td></tr>
<tr><td>GL1343
</td><td></td></tr>
</table>

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Closed flaring wide (mouthed)	
GL2857  	
GL3387  	

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Lugs-handles	
GL1770 	
GL0717 	No available drawing GL0717
GL0802 	

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

Lugs-handles

GL2412

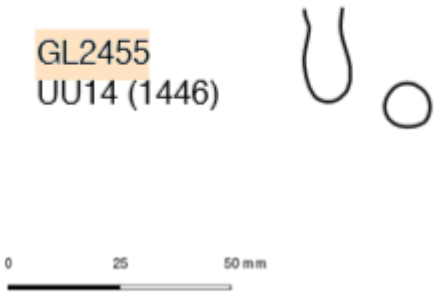




Foot--droplet

GL2455

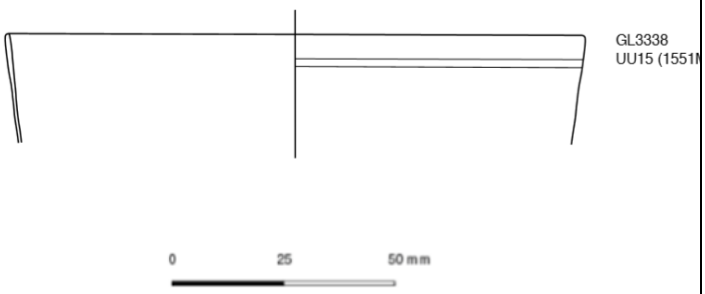




Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

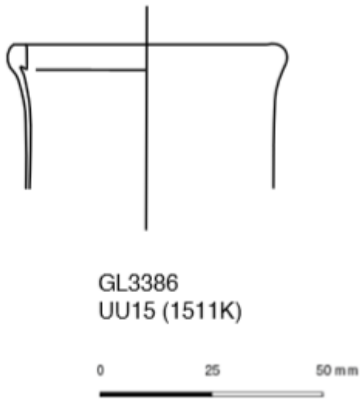
Open flaring-sided	
GL3338 	
GL0943 No available photo	No available drawing GL0943
GL1029 No available photo	No available drawing GL1029

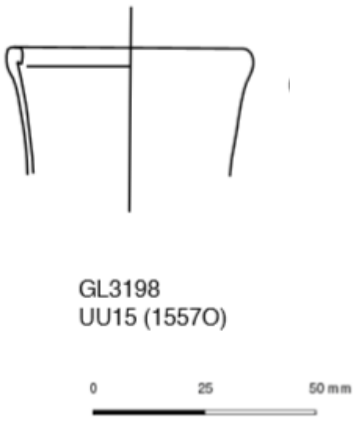
Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair PhD thesis (Blair, 2016).

<table>
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<tr><td>GL3198

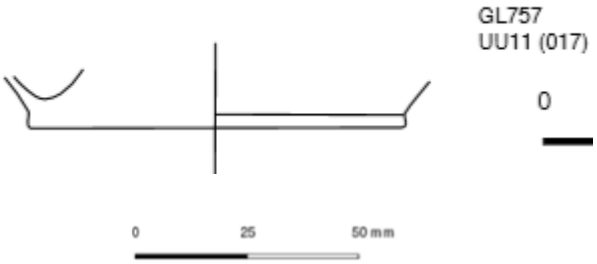
</td><td>
</td></tr>
<tr><td>GL0802

No available photo</td><td>No available drawing GL0802</td></tr>
</table>

Appendix 1

SAMPLE IMAGES/UNGUJA UKUU

Photos and drawings, where available, of the vessels sampled for this project. Photos taken by author, drawings are from Blair (Blair, 2016).

Bases	
GL0757 	
GL0984 	No available drawing GL0984

Appendix 2

Compositional Data EPMA

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Based on the compositional errors produced for repeated analysis of Corning standard B in Tables 5.3 and 5.6 the following relative analytical accuracies are associated with the element oxides listed below. Major and minor elements: 3% for Na_2O, 2.5% for SiO_2, 1.5% for K_2O, 1.5% for CaO, 2% for PbO. Minor elements: 5% for MgO, 2.5% for Al_2O_3, 15.5% for P_2O_5, 6.5% for FeO, 5% for CuO and 13% for Cl.

Table 6.1 Chemical composition of glasses from Kadhima, Mughaira and Shiqaya.

Natron Type

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1798	I	Group I	13.36	0.59	3.08	72.65	0.07	0.09	0.6	0.74	7.57	0.1	0	0.51	0.03	0.03		99.54
St.Dev.			0.18	0.02	0.07	0.33	0.03	0.00	0.02	0.01	0.13	0.01	0.00	0.04	0.01	0.02	0.01	0.30
GL 1051	I	Group I	13.78	0.52	2.92	73.31	0.07	0.09	0.68	0.53	7.48	0.08	0	0.41	0.01	0		99.93
St.Dev.			0.16	0.01	0.02	0.05	0.01	0.01	0.02	0.00	0.04	0.00	0.00	0.01	0.01	0.00	0.01	0.21

Plant-ash Group I

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1234	II	Group I	13.77	3.5	0.93	72.84	0.01	0.29	0.18	1.96	6.18	0.02	0	0.05	0	0		99.94
St.Dev.			0.23	0.08	0.03	0.08	0.01	0.02	0.04	0.03	0.04	0.00	0.00	0.01	0.00	0.00	0.00	0.15
GL 1356	II	Group I	14.41	5.06	1.82	66.61	0.2	0.18	0.51	2.84	5.83	0.11	1.75	0.65	0	0.01		100.22
St.Dev.			0.20	0.06	0.01	0.10	0.04	0.01	0.00	0.04	0.12	0.01	0.18	0.04	0.00	0.01	0.02	0.20
GL 1264	II	Group I	14.55	3.53	2.11	69.42	0.18	0.13	0.77	2.23	5.69	0.13	0.75	0.54	0.01	0		100.2
St.Dev.			0.16	0.03	0.03	0.15	0.03	0.00	0.03	0.02	0.03	0.01	0.03	0.01	0.01	0.00	0.01	0.29
GL 1364	II	Group I	14.61	5.11	1.8	67.11	0.17	0.17	0.48	2.84	5.66	0.11	1.72	0.68	0.03	0.01		100.75
St.Dev.			0.11	0.06	0.04	0.18	0.02	0.01	0.06	0.02	0.16	0.00	0.08	0.04	0.01	0.01	0.01	0.13
GL 1329	II	Group I	15	4.52	1.69	65.77	0.21	0.21	0.55	2.89	6.38	0.12	1.98	0.65	0.01	0.01		100.16
St.Dev.			0.07	0.07	0.08	0.50	0.04	0.01	0.02	0.02	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.56
GL 1848	II	Group I	15.65	6.16	1.18	66.17	0.16	0.29	0.44	2.9	4.79	0.06	1.17	0.29	0.01	0		99.46
St.Dev.			0.20	0.07	0.04	0.13	0.02	0.01	0.03	0.02	0.03	0.00	0.05	0.01	0.01	0.00	0.01	0.36

Appendix 2

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1003	II	Group I	15.81	6.29	1.79	61.35	0.17	0.24	0	4.59	7.11	0.31	0	0.4	0	0		98.38
St.Dev.			0.31	0.07	0.02	0.18	0.01	0.03	0	0.03	0.04	0.04	0.00	0.01	0.00	0.00	0.01	0.51
GL 15	II	Group I	16.07	4.3	1.9	64.45	0.23	0.27	0.64	3.16	6.97	0.15	0.51	0.65	0.01	0		99.53
St.Dev.			0.38	0.08	0.06	0.38	0.01	0.01	0.02	0.03	0.06	0.00	0.03	0.03	0.00	0.00	0.01	0.16
GL 879	II	Group I	16.15	4.78	1.84	62.53	0.21	0.26	0	3.67	7.45	0.32	0	0.46	0	0		97.91
St.Dev.			0.20	0.05	0.02	0.12	0.02	0.02	0	0.05	0.03	0.05	0.00	0.01	0.00	0.00	0.01	0.31
GL 923	II	Group I	16.18	4.72	1.82	62.45	0.22	0.29	0	3.66	7.38	0.34	0	0.44	0	0		97.76
St.Dev.			0.29	0.23	0.05	0.28	0.00	0.05	0	0.01	0.03	0.02	0.00	0.03	0.00	0.00	0.00	0.31
GL 692	II	Group I	16.32	4.65	1.78	62.58	0.21	0.3	0	3.64	7.41	0.33	0	0.44	0	0.01		97.91
St.Dev.			0.16	0.01	0.01	0.16	0.01	0.01	0	0.01	0.03	0.02	0.00	0.02	0.00	0.01	0.01	0.13
GL 85	II	Group I	16.55	7	0.96	65.2	0.15	0.23	0.69	3.45	4.58	0.08	0	0.3	0	0		99.45
St.Dev.			0.31	0.14	0.01	0.09	0.04	0.01	0.06	0.03	0.04	0.01	0.00	0.01	0.00	0.00	0.01	0.51

Plant-ash Group II

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 61	II	Group II a	8.66	6.4	3.69	63.17	0.42	0.29	0	2.66	9.13	0.46	1.27	0.9	0	0.01		97.26
St.Dev.			0.19	0.14	0.04	0.42	0.01	0.01	0	0.04	0.11	0.02	0.09	0.01	0.00	0.02	0.01	0.73
GL 1072	II	Group II a	9.11	7.96	2.95	66.5	0.21	0.32	0	3.3	7.85	0.4	0.38	0.64	0	0.01		99.73
St.Dev.			0.43	0.17	0.08	0.26	0.01	0.01	0	0.05	0.03	0.06	0.15	0.02	0.00	0.01	0.00	0.72
GL 660	II	Group II b	13.81	3.35	2.81	65.58	0.38	0.24	0.65	2.4	9.16	0.19	0	0.98	0	0.01		99.75
St.Dev.			0.20	0.07	0.09	0.09	0.04	0.01	0.04	0.02	0.03	0.00	0.00	0.03	0.00	0.01	0.01	0.17

Plant-ash Group II

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1574	II	Group II b	13.84	3.45	3.83	63.73	0.39	0.19	0.6	2.85	9.11	0.26	0	1.39	0.02	0.01		99.85
St.Dev.			0.15	0.03	0.05	0.18	0.04	0.01	0.01	0.02	0.14	0.00	0.00	0.01	0.01	0.01	0.00	0.16
GL 1308	II	Group II b	13.92	3.7	3.81	63.99	0.46	0.24	0.58	2.45	8.85	0.21	0	1.21	0.02	0		99.61
St.Dev.			0.12	0.06	0.04	0.08	0.01	0.00	0.01	0.01	0.11	0.00	0.00	0.02	0.01	0.01	0.02	0.33
GL 80	II	Group II b	14.18	4.7	3.12	62.97	0.34	0.16	0.67	2.84	8.4	0.19	0.11	1.07	0.01	0		98.95
St.Dev.			0.03	0.01	0.07	0.07	0.02	0.01	0.02	0.01	0.01	0.00	0.02	0.02	0.01	0.00	0.00	0.05
GL 1547	II	Group II b	14.19	4.69	3.13	62.69	0.36	0.16	0.73	2.84	8.36	0.19	0.08	1.1	0.02	0		98.72
St.Dev.			0.12	0.08	0.04	0.11	0.04	0.02	0.02	0.05	0.02	0.01	0.08	0.01	0.01	0.01	0.01	0.25
GL 1616	II	Group II b	14.19	3.14	0	62.56	0.25	0.38	0	2.32	10.2	0.3	0	0.6	0	1.05		96.998
St.Dev.			8.20	1.81	1.15	36.12	0.28	0.12	0	1.34	5.88	0.16	0.00	0.35	0.00	0.60	0.01	55.54
GL 1371	II	Group II b	14.33	4.05	4.04	62.44	0.42	0.15	0.72	2.25	9.49	0.26	0.18	1.34	0.01	0		99.83
St.Dev.			0.09	0.05	0.05	0.05	0.01	0.01	0.05	0.02	0.06	0.01	0.02	0.04	0.01	0.00	0.00	0.29
GL 1680	II	Group II b	14.33	3.43	3.24	63.25	0.31	0.24	0.63	2.51	8.95	0.19	0.72	1.05	0.03	0		99.08
St.Dev.			0.18	0.14	0.08	0.15	0.03	0.01	0.02	0.01	0.11	0.01	0.06	0.03	0.01	0.00	0.01	0.50
GL 81	II	Group II b	14.37	3.74	3.27	63.4	0.4	0.18	0.56	2.61	8.93	0.19	0.76	1.16	0.02	0.01		99.75
St.Dev.			0.07	0.07	0.10	0.16	0.01	0.01	0.03	0.03	0.02	0.00	0.03	0.03	0.00	0.01	0.00	0.33
GL 1603	II	Group II b	14.38	3.51	3.25	63.03	0.33	0.23	0.63	2.5	8.81	0.19	0.65	1.05	0.02	0.01		98.77
St.Dev.			0.34	0.06	0.03	0.12	0.02	0.02	0.08	0.02	0.14	0.00	0.02	0.02	0.01	0.01	0.00	0.40
GL 155	II	Group II b	14.4	4.17	2.2	64.55	0.34	0.19	0.72	2.95	8.2	0.14	0.76	0.85	0	0		99.67
St.Dev.			0.03	0.07	0.06	0.14	0.01	0.02	0.03	0.02	0.04	0.01	0.02	0.02	0.01	0.00	0.00	0.20
GL 83	II	Group II b	14.42	3.51	3.24	62.99	0.33	0.25	0.58	2.52	8.83	0.19	0.7	1.02	0.01	0.01		98.8
St.Dev.			0.23	0.05	0.02	0.23	0.03	0.01	0.03	0.01	0.08	0.00	0.02	0.04	0.01	0.02	0.00	0.38

Appendix 2

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Plant-ash Group II

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1856	II	Group II b	14.44	3.44	3.3	63.79	0.43	0.22	0.59	2.46	9.46	0.21	0	1.12	0.01	0		99.63
St.Dev.			0.10	0.04	0.08	0.19	0.01	0.00	0.02	0.02	0.06	0.00	0.00	0.03	0.01	0.00	0.00	0.26
GL 1213	II	Group II b	14.45	3.94	3.94	61.65	0.42	0.3	0.46	2.16	9.76	0.23	0.84	1.27	0.01	0.01		99.63
St.Dev.			0.03	0.04	0.04	0.24	0.05	0.00	0.05	0.01	0.09	0.00	0.06	0.02	0.01	0.01	0.01	0.30
GL 778	II	Group II b	14.47	3.71	2.63	64.5	0.25	0.21	0.66	2.57	7.64	0.15	1.34	0.83	0	0.02		99.22
St.Dev.			0.12	0.02	0.04	0.20	0.02	0.01	0.02	0.01	0.07	0.00	0.02	0.02	0.00	0.01	0.01	0.36
GL 1588	II	Group II b	14.53	3.22	2.56	63.55	0.37	0.19	0.86	2.41	7.9	0.17	1.98	0.78	0.02	0.01		98.72
St.Dev.			0.31	0.04	0.06	0.19	0.03	0.01	0.06	0.01	0.05	0.01	0.04	0.01	0.02	0.01	0.00	0.47
GL 218	II	Group II b	14.57	3.43	3.2	63.04	0.31	0.24	0.58	2.51	8.91	0.19	0.72	1.09	0.02	0		99.05
St.Dev.			0.16	0.05	0.05	0.40	0.01	0.02	0.05	0.04	0.03	0.01	0.05	0.03	0.02	0.00	0.02	0.42
GL 1323	II	Group II b	14.6	4.01	3.47	62.38	0.39	0.24	0.46	2.67	9.26	0.21	0.53	1.12	0.01	0.01		99.58
St.Dev.			0.45	0.13	0.05	0.09	0.03	0.01	0.07	0.01	0.24	0.00	0.06	0.07	0.01	0.01	0.00	0.70
GL 998	II	Group II b	14.67	3.18	3.15	63.77	0.37	0.23	0.74	2.8	7.67	0.18	1.78	0.88	0.02	0		99.65
St.Dev.			0.29	0.04	0.08	0.18	0.05	0.00	0.04	0.01	0.03	0.01	0.25	0.05	0.02	0.00	0.01	0.35
GL 236	II	Group II b	14.66	3.62	3.69	61.86	0.48	0.24	0.5	2.8	9.29	0.23	0.17	1.22	0.03	0.01		99
St.Dev.			0.19	0.14	0.04	0.14	0.02	0.01	0.05	0.04	0.07	0.00	0.04	0.03	0.01	0.01	0.01	0.04

Plant-ash Group II

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1677	II	Group II b	14.76	3.21	2.63	63.53	0.39	0.2	0.86	2.44	7.97	0.18	1.97	0.78	0.02	0		99.1
St.Dev.			0.07	0.02	0.10	0.20	0.03	0.00	0.04	0.01	0.06	0.01	0.03	0.03	0.02	0.00	0.00	0.18

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 2041	II	Group II b	14.82	3.72	3.08	63.03	0.37	0.24	0.7	2.41	9.08	0.18	0.98	1.02	0.01	0.01		99.86
St.Dev.			0.08	0.02	0.05	0.11	0.04	0.01	0.02	0.02	0.10	0.01	0.08	0.02	0.01	0.01	0.00	0.28
GL 736	II	Group II b	14.84	3.13	2.88	63.57	0.32	0.34	0.5	3.04	8.72	0.19	0.57	0.8	0.01	0		99.09
St.Dev.			0.25	0.08	0.05	0.31	0.05	0.01	0.02	0.07	0.10	0.00	0.03	0.01	0.01	0.01	0.02	0.37
GL 1060	II	Group II b	14.85	2.95	3	63.42	0.3	0.23	0.83	2.01	8.54	0.2	2.07	0.97	0.02	0.01		99.56
St.Dev.			0.30	0.04	0.02	0.22	0.02	0.01	0.03	0.01	0.06	0.00	0.10	0.02	0.01	0.01	0.01	0.49
GL 1132	II	Group II b	15.08	2.95	3.05	63.26	0.29	0.21	0.81	2.02	8.57	0.19	2.15	0.96	0.01	0		99.73
St.Dev.			0.29	0.06	0.05	0.71	0.01	0.01	0.00	0.01	0.08	0.01	0.05	0.01	0.01	0.01	0.01	0.40
GL 1152	II	Group II b	15.15	3.06	2.92	63.33	0.34	0.36	0.52	3.1	8.7	0.2	0.57	0.81	0	0		99.26
St.Dev.			0.16	0.03	0.05	0.03	0.01	0.01	0.03	0.01	0.03	0.00	0.04	0.02	0.00	0.01	0.02	0.19
GL 1947	II	Group II b	15.25	4.59	4.26	61.24	0.41	0.28	0.47	2.52	9.29	0.25	0	1.47	0.01	0		100.21
St.Dev.			0.04	0.06	0.03	0.08	0.03	0.01	0.03	0.01	0.07	0.01	0.00	0.00	0.01	0.01	0.00	0.05
GL 1335	II	Group II b	15.28	3.66	2.71	63.67	0.87	0.25	0.61	2.79	7.88	0.18	2.02	0.89	0.02	0	0	100.43
St.Dev.			0.08	0.09	0.03	0.04	0.02	0.01	0.02	0.02	0.04	0.01	0.17	0.02	0.00	0.01	0.01	0.19
GL 151	II	Group II b	15.31	5.44	2.82	63.22	0.3	0.26	0.51	2.65	8.13	0.2	0	0.94	0.03	0.03	0.01	100.03
St.Dev.			0.14	0.03	0.06	0.11	0.04	0.02	0.02	0.03	0.02	0.00	0.00	0.03	0.00	0.01	0.01	0.23
GL 771	II	Group II b	15.4	3.1	2.28	64.47	0.27	0.25	0.68	3.1	8.14	0.18	1.62	0.94	0.02	0.03		100.72
St.Dev.			0.30	0.01	0.06	0.28	0.03	0.01	0.02	0.01	0.03	0.00	0.06	0.04	0.01	0.01	0.02	0.14
GL 1577	II	Group II b	15.41	3.08	2.31	63.92	0.36	0.25	0.69	3.12	8.1	0.17	1.62	0.93	0	0.04		100.26
St.Dev.			0.25	0.08	0.05	0.31	0.05	0.01	0.02	0.07	0.10	0.00	0.03	0.01	0.01	0.01	0.02	0.37
GL 838	II	Group II b	15.44	3.29	3.69	61.21	0.39	0.24	0	2.34	9.06	0.24	1.77	1.22	0.02	0		99.69
St.Dev.			0.14	0.07	0.16	0.21	0.02	0.00	0.02	0.02	0.04	0.00	0.05	0.04	0.02	0.00	0.01	0.60

Appendix 2

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1995	II	Group II b	15.92	4.45	3.13	62.8	0.35	0.22	0.69	2.85	7.48	0.17	0	1.05	0.019	0.43		99.85
St.Dev.			0.24	0.11	0.03	0.05	0.02	0.01	0.04	0.03	0.03	0.01	0.00	0.06	0.01	0.03	0.01	0.23
GL 898	II	Group II b	15.94	5.25	2.5	61.07	0.35	0.18	0.59	3.31	9.24	0.12	0.13	0.73	0.01	0.01		99.63
St.Dev.			0.23	0.04	0.06	0.09	0.01	0.00	0.03	0.02	0.15	0.00	0.02	0.04	0.01	0.01	0.01	0.02
GL 1077	II	Group II b	15.97	4.85	3.64	62.14	0.34	0.26	0.59	2.86	8.4	0.18	0	1.02	0.01	0.02		100.47
St.Dev.			0.05	0.03	0.03	0.04	0.02	0.01	0.03	0.03	0.11	0.01	0.00	0.05	0.01	0.02	0.00	0.25
GL 1381	II	Group II b	16.03	3.45	3.34	62.12	0.3	0.31	0.68	3.03	7.66	0.19	1.86	0.87	0.01	0.01		100.06
St.Dev.			0.15	0.01	0.04	0.04	0.05	0.01	0.04	0.03	0.02	0.01	0.05	0.02	0.01	0.01	0.01	0.35
GL 1062	II	Group II b	16.06	4.18	2.97	63.52	0.27	0.32	0.54	2.52	8.32	0.16	0	1.12	0.03	0.05		100.27
St.Dev.			0.33	0.04	0.13	0.19	0.01	0.02	0.04	0.02	0.10	0.01	0.00	0.01	0.02	0.00	0.03	0.26
GL 1761	II	Group II b	16.12	4.68	2.91	62.69	0.29	0.24	0.64	2.84	7.73	0.16	0	1.07	0.02	0.05		99.66
St.Dev.			0.33	0.16	0.11	0.18	0.01	0.02	0.03	0.03	0.11	0.01	0.00	0.12	0.01	0.01	0.01	0.83
GL 1114	II	Group II b	16.23	5.65	2.28	60.95	0.22	0.21	0.65	4.45	7.76	0.1	0.11	0.58	0.01	0.02		99.56
St.Dev.			0.13	0.10	0.06	0.07	0.00	0.01	0.01	0.02	0.02	0.01	0.03	0.02	0.01	0.02	0.01	0.32
GL 1281	II	Group II b	16.28	2.67	2.67	62.54	0.25	0.3	0	2.86	8.52	0.35	0	0.69	0	0.02		97.36
St.Dev.			0.08	0.06	0.04	0.01	0.01	0.02	0.00	0.02	0.03	0.03	0.00	0.02	0.00	0.01	0.02	0.06
GL 1269	II	Group II b	16.47	5.77	2.83	56.92	0.22	0.21	0	5.55	9.45	0.33	0	0.56	0	0.01		98.66
St.Dev.			0.10	0.04	0.04	0.20	0.00	0.03	0.00	0.02	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.22
GL 232	II	Group II b	16.48	4.25	3.39	60.46	0.29	0.32	0	2.89	8.75	0.4	0	0.92	0	0.05		98.42
St.Dev.			0.45	0.06	0.01	0.07	0.01	0.04	0.00	0.05	0.04	0.02	0.00	0.02	0.00	0.03	0.01	0.34

Plant-ash Group II

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 72	II	Group II b	16.82	4.28	3.25	62.07	0.33	0.16	0.95	1.32	7.63	0.25	0	1.07	0.01	1.5		100.13
St.Dev.			0.11	0.04	0.05	0.26	0.03	0.01	0.09	0.03	0.05	0.01	0.00	0.03	0.01	0.11	0.01	0.08
GL 235	II	Group II b	17.45	3.99	2.88	64.1	0.36	0.24	0.78	2.21	7.08	0.18	0	1.02	0.01	0.01		100.48
St.Dev.			0.28	0.08	0.07	0.03	0.05	0.00	0.04	0.01	0.08	0.01	0.00	0.07	0.01	0.01	0.01	0.18
GL 1674	II	Group II b	17.78	6.12	2.38	60.58	0.18	0.32	0.49	3.06	7.1	0.16	0.27	0.74	0.01	0		99.43
St.Dev.			0.13	0.09	0.02	0.11	0.03	0.00	0.03	0.03	0.06	0.01	0.02	0.03	0.01	0.01	0.01	0.17
GL 1236	II	Group II b	17.81	3.97	3.58	63.13	0.33	0.25	0.91	2.05	7.31	0.21	0	1	0.01	0.01		100.74
St.Dev.		2.12	0.11	0.07	1.15	0.01	0.02	0.04	0.04	0.08	0.01	0.00	0.03	0.02	0.01	0.01	0.79	

Plant-ash Group III

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1118	II	Group IIIa	8.06	5.45	5.47	63.25	0.5	0.18	0	1.53	11.27	0.59	0	1.47	0	0		97.92
St.Dev.			0.41	0.01	0.02	0.96	0.04	0.04	0.00	0.06	0.21	0.04	0.00	0.05	0.00	0.00	0.01	1.40
GL 725	II	Group IIIa	8.12	4.07	3.4	66.61	0.34	0.35	0	3.34	10.19	0.53	2.21	0.92	0	0.05		100.44
St.Dev.			0.31	0.03	0.02	0.44	0.02	0.06	0.00	0.04	0.09	0.03	0.02	0.01	0.00	0.01	0.01	0.64
GL 1652	II	Group IIIa	8.17	5.03	4.39	65.6	0.44	0.21	0	2.56	10.6	0.56	1.71	1.07	0	0.02		100.57
St.Dev.			0.06	0.04	0.09	0.32	0.03	0.03	0.00	0.03	0.03	0.01	0.05	0.14	0.00	0.01	0.02	0.16
GL 1230	II	Group IIIa	8.3	6.83	4.43	63.26	0.55	0.22	0	2.33	10.79	0.51	0	0.97	0	0.01		98.34
St.Dev.			0.22	0.07	0.04	0.62	0.02	0.03	0.00	0.06	0.12	0.04	0.00	0.05	0.00	0.01	0.01	0.73
GL 1662	II	Group IIIa	8.36	5.2	3.93	63.46	0.4	0.33	0	2.39	11.47	0.47	0.2	0.99	0	0.02		97.37
St.Dev.			0.26	0.01	0.03	0.55	0.02	0.05	0.00	0.04	0.07	0.02	0.08	0.05	0.00	0.01	0.00	0.43

Appendix 2

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 149	II	Group IIIa	8.67	6.54	4.07	64.26	0.47	0.28	0	2.8	10.41	0.61	0	0.97	0	0.01		99.22
St.Dev.			0.21	0.02	0.04	0.09	0.00	0.04	0.00	0.02	0.02	0.10	0.10	0.03	0.00	0.00	0.00	0.23
GL 150	II	Group IIIa	8.72	5.91	4.95	62.36	0.37	0.47	0	2.69	10.4	0.6	0	1.24	0	0		97.91
St.Dev.			0.40	0.05	0.11	0.16	0.01	0.03	0.00	0.03	0.02	0.02	0.00	0.04	0.00	0.01	0.00	0.70
GL 1561	II	Group IIIa	8.82	5.9	4.96	62.24	0.36	0.42	0	2.73	10.45	0.62	0	1.33	0.01	0		98.02
St.Dev.			0.33	0.05	0.04	0.72	0.01	0.03	0.00	0.03	0.04	0.04	0.00	0.04	0.02	0.00	0.01	0.68
GL 1039	II	Group IIIa	8.82	6.19	3.82	64	0.37	0.4	0	2.81	11.55	0.52	0	0.86	0	0.01		99.59
St.Dev.			0.36	0.12	0.03	0.23	0.01	0.02	0.00	0.05	0.19	0.00	0.00	0.02	0.00	0.01	0.01	0.82
GL 2068	II	Group IIIa	8.91	5.61	4.52	64.41	0.38	0.47	0	2.6	11.88	0.52	0	1.11	0	0.01		100.57
St.Dev.			0.12	0.09	0.00	0.04	0.02	0.03	0.00	0.02	0.17	0.01	0.00	0.02	0.00	0.01	0.00	0.28
GL 861	II	Group IIIa	8.91	6.08	4.13	62.91	0.45	0.3	0	2.05	12.09	0.52	0	1.03	0	0		98.6
St.Dev.			0.04	0.04	0.04	0.16	0.01	0.06	0.00	0.01	0.05	0.03	0.00	0.04	0.01	0.00	0.00	0.16
GL 269	II	Group IIIa	8.99	5.26	5.03	63.22	0.5	0.36	0	2.86	10.82	0.48	0	1.32	0.07	0		99.14
St.Dev.			0.39	0.07	0.13	0.49	0.02	0.03	0.00	0.06	0.02	0.05	0.00	0.04	0.12	0.00	0.01	0.49
GL 559	II	Group IIIa	9.48	5.56	4.17	62.31	0.73	0.34	0	2.87	11.81	0.48	1.06	0.95	0	0.01		99.98
St.Dev.			0.06	0.04	0.03	0.29	0.65	0.01	0.00	0.03	0.09	0.04	0.07	0.03	0.00	0.00	0.00	0.84
GL 779	II	Group IIIa	9.56	5.2	4.54	63.61	0.33	0.29	0	2.6	10.86	0.51	1.93	1.04	0	0.01		100.65
St.Dev.			0.27	0.14	0.07	0.43	0.02	0.02	0.00	0.02	0.13	0.02	0.16	0.04	0.00	0.00	0.02	1.01

Plant-ash Group III

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 258	II	Group IIIa	9.68	5.6	4.85	60.49	0.49	0.3	0	2.75	12.44	0.57	0	1.26	0	0.01		98.69
St.Dev.			0.15	0.04	0.03	0.19	0.00	0.04	0.00	0.01	0.11	0.05	0.00	0.03	0.00	0.01	0.00	0.14
GL 1808	II	Group IIIa	10.67	5.78	5.4	59.38	0.5	0.34	0	2.63	13.05	0.65	0	1.61	0	0.01		100.19
St.Dev.			0.33	0.34	0.35	0.24	0.00	0.03	0.00	0.03	0.15	0.03	0.00	0.03	0.00	0.01	0.02	1.05
GL 1944	II	Group IIIb	14.16	4.76	4.82	58.59	0.53	0.22	0.65	2.1	11.61	0.28	0	1.71	0.02	0.01		99.62
St.Dev.			0.19	0.03	0.07	0.27	0.04	0.01	0.00	0.02	0.01	0.01	0.00	0.03	0.02	0.01	0.01	0.34
GL 1556	II	Group IIIb	14.21	4.59	3.55	60.61	0.36	0.21	0.46	2.45	11.61	0.23	0	1.26	0.01	0.01		99.73
St.Dev.			0.27	0.04	0.18	0.13	0.00	0.01	0.05	0.01	0.12	0.01	0.00	0.04	0.01	0.01	0.00	0.46
GL 233	II	Group IIIb	14.27	3.97	3.68	60.98	0.42	0.38	0.37	2.5	10.34	0.25	0	1.48	0.01	0		98.84
St.Dev.			0.22	0.05	0.03	0.09	0.02	0.01	0.03	0.01	0.04	0.00	0.00	0.03	0.01	0.01	0.02	0.19
GL 1530	II	Group IIIb	14.37	5.82	3.09	59.03	0.35	0.27	0.35	2.92	11.45	0.2	0	1.06	0.01	0	0.01	99.15
St.Dev.			0.12	0.01	0.04	0.40	0.07	0.01	0.01	0.02	0.15	0.01	0.00	0.01	0.02	0.00	0.00	0.53
GL 773	II	Group IIIb	14.38	3.89	3.87	59.74	0.4	0.32	0.4	2.66	10.06	0.24	2.21	1.42	0.04	0.01		99.85
St.Dev.			0.22	0.03	0.03	0.04	0.04	0.01	0.03	0.01	0.13	0.01	0.03	0.05	0.02	0.01	0.00	0.16
GL 719	II	Group IIIb	14.45	4.16	4.59	61.33	0.41	0.21	0.68	1.78	10.4	0.25	0	1.55	0.01	0		99.97
St.Dev.			0.16	0.03	0.07	0.19	0.04	0.01	0.03	0.01	0.06	0.01	0.00	0.06	0.02	0.00	0.01	0.18
GL 7	II	Group IIIb	14.58	4.26	4.36	59.49	0.35	0.16	0.83	1.41	12.48	0.24	0	1.41	0.02	0		99.71
St.Dev.			0.07	0.12	0.03	0.06	0.05	0.01	0.02	0.02	0.07	0.00	0.00	0.03	0.02	0.00	0.00	0.14
GL 84	II	Group IIIb	14.58	3.98	3.31	62.91	0.32	0.18	0.6	2.25	10.02	0.19	0	1.01	0.01	0		99.49
St.Dev.			0.15	0.03	0.15	0.32	0.05	0.01	0.03	0.02	0.04	0.00	0.00	0.02	0.01	0.00	0.01	0.44

Appendix 2

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1223	II	Group IIIb	14.6	3.98	3.66	61.67	0.54	0.26	0.51	2.24	10.69	0.25	0	1.5	0.03	0		100.08
St.Dev.																		
GL 2041	II	Group IIIb	14.62	4.18	3.92	60.13	0.34	0.31	0.42	2.6	10.37	0.24	0.88	1.53	0.02	0.04		99.87
St.Dev.																		
GL 651	II	Group IIIb	14.66	4.19	4.15	58.53	0.35	0.21	0.62	1.55	11.59	0.22	1.37	1.34	0	0.01		98.92
St.Dev.			0.16	0.14	0.04	0.21	0.04	0.00	0.01	0.01	0.06	0.01	0.06	0.06	0.00	0.00	0.01	0.35
GL 361	II	Group IIIb	14.69	4.55	4.35	59.82	0.35	0.27	0.57	1.68	11.67	0.25	0	1.47	0.04	0.01		99.87
St.Dev.			0.19	0.09	0.01	0.09	0.03	0.02	0.01	0.01	0.10	0.00	0.00	0.02	0.01	0.01	0.00	0.41
GL 2045	II	Group IIIb	14.83	4.33	4.12	58.77	0.35	0.21	0.64	1.53	11.55	0.22	1.42	1.35	0.02	0.01		99.47
St.Dev.			0.24	0.04	0.07	0.29	0.02	0.01	0.05	0.01	0.06	0.01	0.08	0.02	0.01	0.01	0.00	0.50
GL 1351	II	Group IIIb	15.02	4.03	3.34	63.06	0.34	0.18	0.64	2.26	10	0.19	0	0.99	0.01	0		100.24
St.Dev.			0.17	0.03	0.03	0.04	0.03	0.00	0.02	0.03	0.01	0.00	0.00	0.02	0.02	0.00	0.00	0.07
GL 1004	II	Group IIIb	15.02	4.41	4.23	59.92	0.36	0.27	0.71	1.7	11.6	0.25	0	1.48	0.04	0		100.17
St.Dev.			0.46	0.04	0.01	0.16	0.02	0.01	0.02	0.01	0.03	0.00	0.11	0.01	0.01	0.00	0.01	0.51
GL 82	II	Group IIIb	15.02	4.41	4.23	59.92	0.36	0.27	0.71	1.7	11.6	0.25	0	1.48	0.04	0		100.17
St.Dev.			0.25	0.05	0.07	0.13	0.04	0.01	0.00	0.02	0.10	0.00	0.00	0.04	0.02	0.00	0.02	0.34
GL 1363	II	Group IIIb	15.04	5.14	4.26	58.5	0.38	0.38	0.4	2.81	10.49	0.26	0	1.54	0.03	0.01		99.44
St.Dev.			0.36	0.01	0.04	0.12	0.06	0.01	0.00	0.03	0.12	0.01	0.00	0.02	0.01	0.01	0.00	0.41
GL 396	II	Group IIIb	15.05	4.07	3.50	59.74	0.34	0.30	0.40	2.33	10.76	0.20	0.74	1.25	0.02	0.03	0.00	98.98
St.Dev.			0.30	0.14	0.04	0.06	0.04	0.01	0.02	0.02	0.04	0.01	0.06	0.05	0.01	0.01	0.00	0.46
GL 152	II	Group IIIb	15.28	4.14	4.06	59.37	0.42	0.27	0.55	2.24	11.32	0.23	0	1.29	0.03	0.01		99.36
St.Dev.			0.45	0.05	0.10	0.67	0.05	0.03	0.07	0.02	0.05	0.01	0.00	0.02	0.02	0.00	0.02	0.37

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_2	CuO	Zn	Total
GL 640	II	Group IIIb	15.23	4.16	4.3	59.24	0.31	0.2	0	2.38	10.9	0.51	0	1.08	0	0		98.5
St.Dev.			0.08	0.01	0.04	0.10	0.02	0.01	0.00	0.02	0.10	0.01	0.00	0.02	0.00	0.00	0.01	0.33
GL 659	II	Group IIIb	15.26	4.44	3.38	59.81	0.29	0.36	0.33	2.31	12.15	0.22	0	1.07	0.02	0.01		99.81
St.Dev.			0.35	0.02	0.03	0.13	0.03	0.03	0.07	0.02	0.06	0.01	0.00	0.04	0.02	0.00	0.01	0.31
GL 1675	II	Group IIIb	15.29	4.15	4	59.27	0.36	0.24	0	19.23	10.8	0.5	0	1.07	0	0.02		98.62
St.Dev.			0.66	0.05	0.03	0.13	0.02	0.02	0.00	0.03	0.00	0.02	0.00	0.02	0.00	0.00	0.01	0.48
GL 2110	II	Group IIIb	15.47	4.12	4.15	58.85	0.33	0.3	0.56	1.58	11.73	0.23	0.72	1.37	0.01	0.01		99.59
St.Dev.			0.19	0.01	0.04	0.11	0.03	0.01	0.01	0.01	0.09	0.01	0.01	0.06	0.02	0.01	0.02	0.15
GL 1786	II	Group IIIb	15.5	4.14	4.11	59.77	0.41	0.26	0.54	2.27	11.12	0.23	0	1.27	0.03	0		99.8
St.Dev.			0.47	0.09	0.08	0.22	0.01	0.02	0.03	0.01	0.07	0.00	0.00	0.04	0.03	0.00	0.00	0.10
GL 14	II	Group IIIb	15.58	4.64	4.22	59	0.44	0.39	0.4	2.44	10.33	0.26	0	1.52	0.02	0.01		99.45
St.Dev.			0.16	0.07	0.03	0.05	0.05	0.01	0.04	0.01	0.01	0.01	0.00	0.04	0.02	0.02	0.01	0.12
GL 534	II	Group IIIb	15.7	4.17	3.44	60.78	0.29	0.39	0.41	2.55	10.7	0.22	0	1.3	0.02	0		100.16
St.Dev.			0.15	0.02	0.06	0.07	0.02	0.01	0.04	0.01	0.09	0.01	0.00	0.04	0.02	0.00	0.01	0.08
GL 639	II	Group IIIb	16.71	4.89	3.45	59.3	0.38	0.34	0.45	2.1	10.78	0.2	0	1.11	0.02	0.01		99.88
St.Dev.			0.08	0.05	0.06	0.11	0.03	0.01	0.03	0.01	0.02	0.01	0.00	0.02	0.01	0.01	0.01	0.21
GL 718	II	Group IIIb	16.99	4.32	3.58	59.79	0.27	0.41	0.52	2.24	10.33	0.22	0	1.12	0	0.01		99.96
St.Dev.			0.13	0.08	0.01	0.07	0.05	0.02	0.03	0.05	0.05	0.00	0.00	0.04	0.01	0.01	0.01	0.05

Appendix 2

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Plant-ash Group IV

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1398	II	Group IV	8.01	2.88	4.04	66.76	0.34	0.29	0.00	3.71	7.86	0.11	4.43	0.88	0	0		99.53
St.Dev.			0.17	0.07	0.08	0.23	0.01	0.04	0.00	0.01	0.10	0.11	0.10	0.04	0.00	0.01	0.01	0.12
GL 1404	II	Group IV	8.01	2.89	4.09	66.61	0.34	0.29	0.00	3.63	8.01	0.14	4.37	0.88	0	0		99.45
St.Dev.			4.62	1.67	2.36	38.46	0.06	0.17	0.00	2.09	4.62	0.10	2.52	0.50	0.00	0.00	0.01	57.12
GL 1412	II	Group IV	8.06	2.91	4.1	67.33	0.35	0.28	0.00	3.75	8.2	0.08	4.57	0.91	0	0		100.69
St.Dev.			0.20	0.03	0.02	0.25	0.03	0.04	0.00	0.01	0.02	0.08	0.11	0.02	0.00	0.00	0.00	0.61
GL 1394	II	Group IV	8.06	2.94	4.11	66.68	0.34	0.29	0.00	3.72	8.2	0.1	4.35	0.89	0	0.01		99.86
St.Dev.			0.03	0.06	0.07	0.16	0.01	0.02	0.00	0.03	0.04	0.07	0.10	0.05	0.00	0.01	0.01	0.18
GL 1414	II	Group IV	8.07	2.94	4.09	67.48	0.35	0.29	0.00	3.79	8.17	0.11	4.63	0.91	0	0		101.06
St.Dev.			0.28	0.02	0.06	0.07	0.02	0.06	0.00	0.01	0.12	0.05	0.09	0.03	0.00	0.00	0.01	0.48
GL 1395	II	Group IV	8.08	2.88	4.16	66.65	0.34	0.27	0.00	3.67	7.99	0.13	4.34	0.9	0	0.01		99.62
St.Dev.			0.26	0.03	0.10	0.22	0.01	0.03	0.00	0.03	0.05	0.09	0.10	0.05	0.00	0.01	0.01	0.35
GL 1400	II	Group IV	8.09	2.94	4.05	66.67	0.34	0.29	0.00	3.71	7.93	0.12	4.42	0.89	0	0		99.64
St.Dev.																		
GL 1417	II	Group IV	8.2	2.94	4.11	67.57	0.34	0.32		3.8	8.16	0.1	4.48	0.91	0	0		101.1
St.Dev.			0.12	0.03	0.01	0.06	0.02	0.02	0.00	0.02	0.03	0.09	0.06	0.02	0.00	0.01	0.01	0.09
GL 1408	II	Group IV	8.21	2.96	4.05	66.72	0.35	0.28		3.66	7.91	0.11	4.31	0.89	0	0.01		99.7
St.Dev.			0.08	0.04	0.04	0.19	0.01	0.04	0.00	0.06	0.20	0.11	0.07	0.03	0.00	0.01	0.01	0.65
GL 1407	II	Group IV	8.31	2.95	4.13	66.58	0.35	0.25		3.71	8	0.1	4.33	0.9	0	0		99.79
St.Dev.			0.16	0.05	0.04	0.19	0.00	0.04	0.00	0.03	0.05	0.08	0.12	0.05	0.00	0.00	0.02	0.27

Plant-ash Group IV

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1393	II	Group IV	8.36	2.94	4.08	66.82	0.32	0.28	0.00	3.73	7.84	0.13	4.44	0.89	0	0.01		100.05
St.Dev.			0.30	0.02	0.06	0.11	0.02	0.00	0.00	0.03	0.24	0.11	0.03	0.02	0.00	0.01	0.01	0.49
GL 1406	II	Group IV	8.36	2.9	4.07	66.39	0.34	0.3	0.00	3.7	8	0.06	4.32	0.89	0	0		99.54
St.Dev.			0.12	0.08	0.04	0.20	0.01	0.09	0.00	0.03	0.05	0.07	0.08	0.04	0.00	0.00	0.01	0.20
GL 1418	II	Group IV	8.43	2.97	4.11	67.29	0.36	0.29	0.00	3.84	8.25	0.08	4.57	0.96	0	0		101.37
St.Dev.			0.19	0.03	0.06	0.26	0.02	0.03	0.00	0.02	0.08	0.05	0.14	0.02	0.00	0.00	0.00	0.36
GL 1410	II	Group IV	8.52	2.91	4.01	65.69	0.33	0.3	0.00	3.73	8	0.1	4.08	0.88	0	0		98.73
St.Dev.			0.29	0.08	0.10	0.40	0.00	0.03	0.00	0.03	0.08	0.07	0.15	0.01	0.00	0.00	0.01	0.95
GL 1411	II	Group IV	8.59	2.92	4.1	66.34	0.32	0.25	0.00	3.75	8	0.08	4.5	0.91	0	0.01		100.03
St.Dev.			0.49	0.07	0.01	0.12	0.02	0.04	0.00	0.01	0.03	0.07	0.09	0.06	0.00	0.01	0.01	0.42
GL 1413	II	Group IV	8.64	2.92	4.14	67.54	0.35	0.31	0.00	3.79	8.21	0.21	4.63	0.92	0	0		101.92
St.Dev.			0.07	0.01	0.05	0.14	0.01	0.07	0.00	0.04	0.02	0.10	0.16	0.03	0.00	0.00	0.02	0.16
GL 1409	II	Group IV	9.18	2.91	4.04	65.89	0.31	0.29	0.00	3.71	7.9	0.07	4.3	0.86	0	0.01		99.67
St.Dev.			1.23	0.09	0.07	0.27	0.00	0.03	0.00	0.10	0.14	0.08	0.25	0.02	0.00	0.01	0.01	1.13
GL 1599	II	Group IV	18.04	4.6	3.96	61.74	0.26	0.27	0.75	2.34	7.31	0.16	0	1.05	0.02	0		100.68
St.Dev.			0.24	0.04	0.03	0.09	0.01	0.01	0.02	0.02	0.06	0.01	0.00	0.01	0.01	0.00	0.01	0.31

Appendix 2

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Outliers

Plant-ash Group IV

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 957	II		0.14	0.69	2.49	18.71	0.21	0.29	0.21	0.43	31.45	0.16	1.19	0.79	0.01	0.01		56.94
St.Dev.			0.06	0.07	0.20	3.97	0.10	0.07	0.04	0.06	4.99	0.01	0.42	0.05	0.01	0.01	0.01	1.29
GL 8	II	Group I	7.76	8.04	1.47	69.87	0.12	0.3	0	2.87	7.4	0.2	0	0.32	0	0		98.6
St.Dev.			0.01	0.01	0.06	0.11	0.01	0.04	0.00	0.00	0.09	0.01	0.00	0.01	0.00	0.01	0.01	0.16
GL 748	II	Group II a	5.26	4.85	3.2	69.76	0.44	0.14	0	1.82	6.97	0.42	0	0.74	0	0		93.71
St.Dev.			0.20	0.12	0.06	0.22	0.02	0.05	0.00	0.01	0.04	0.01	0.00	0.02	0.00	0.00	0.00	0.58
GL 2142	II	Group II a	5.82	4.68	2.57	73.29	0.38	0.16	0	3.19	6.99	0.12	0.52	0.72	0	0.01		98.65
St.Dev.			0.14	0.06	0.05	0.23	0.01	0.02	0.00	0.01	0.04	0.10	0.02	0.01	0.00	0.01	0.00	0.49
GL 1007	II	Group II a	5.83	3.82	2.41	69.01	0.32	0.2	0	2.58	8.03	0.38	1.24	0.56	0	0.02		94.58
St.Dev.			0.12	0.03	0.02	0.12	0.01	0.03	0.00	0.02	0.05	0.02	0.05	0.03	0.00	0.01	0.00	0.19
GL 299	II	Group II a	6.08	3.96	3.98	66.94	0.49	0.24	0	2.61	9.63	0.49	0	0.93	0	0		95.49
St.Dev.			0.54	0.04	0.04	0.48	0.00	0.04	0.00	0.03	0.02	0.02	0.00	0.02	0.00	0.01	0.01	0.70
GL 1302	II	Group II a	6.57	3.38	2.84	66.41	0.35	0.2	0	2.88	8.65	0.44	2.41	0.62	0	0		94.93
St.Dev.			0.26	0.00	0.02	0.35	0.01	0.02	0.00	0.01	0.04	0.02	0.11	0.03	0.00	0.00	0.00	0.48
GL 1419	II	Group II a	6.62	4.90	2.80	72.58	0.26	0.22	0.00	3.45	7.28	0.11	0.98	0.58	0.00	0.00	0.00	99.97
St.Dev.			0.10	0.11	0.04	0.14	0.01	0.04	0.00	0.03	0.05	0.11	0.10	0.01	0.00	0.00	0.00	0.16
GL 854	II	Group II a	6.79	4.68	4.01	69.24	0.47	0.16	0	2.75	9.74	0.51	0.36	0.99	0	0.01		99.85
St.Dev.			0.39	0.04	0.03	0.20	0.00	0.01	0.00	0.01	0.08	0.04	0.12	0.03	0.00	0.01	0.02	0.23
GL 1474	II	Group II a	6.9	3.56	2.61	66.61	0.33	0.26	0	3.22	8.38	0.49	1.98	0.84	0	0.04		95.5
St.Dev.			0.12	0.05	0.05	0.12	0.01	0.03	0.00	0.02	0.06	0.03	0.19	0.03	0.00	0.01	0.01	0.26

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1009	II	Group II a	7.19	3.63	2.59	66.37	0.36	0.28	0	3.28	8.41	0.44	1.9	0.79	0	0.01		95.44
St.Dev.			0.09	0.09	0.03	0.28	0.01	0.03	0.00	0.03	0.03	0.03	0.28	0.05	0.00	0.00	0.01	0.46
GL 1461	II	Group II a	7.2	3.65	2.64	66.56	0.35	0.26	0	3.26	8.43	0.43	2.16	0.76	0	0.02		96.01
St.Dev.			0.27	0.01	0.01	0.10	0.02	0.02	0.00	0.01	0.06	0.02	0.02	0.02	0.00	0.01	0.00	0.25
GL 1844	II	Group II a	7.21	5.63	2.34	70.09	0.26	0.21	0	3.39	7.73	0.38	0.89	0.55	0	0		98.87
St.Dev.			0.19	0.06	0.02	0.11	0.02	0.01	0.00	0.01	0.16	0.02	0.03	0.01	0.00	0.01	0.01	0.28
GL 584	II	Group II a	7.31	3.5	2.94	66.16	0.31	0.22	0	3	9.25	0.48	2.23	0.7	0	0		96.29
St.Dev.			0.26	0.17	0.12	0.68	0.02	0.01	0.00	0.04	0.24	0.01	0.04	0.04	0.00	0.00	0.02	0.12
GL 1435	II	Group II a	7.38	3.42	3.07	65.73	0.38	0.26	0	2.99	8.73	0.41	2.78	0.64	0.00	0.00	0.01	95.93
St.Dev.			0.78	0.07	0.38	1.47	0.07	0.07	0.00	0.23	0.25	0.05	0.47	0.02	0.00	0.00	0.01	0.84
GL 953	II	Group II a	7.66	5.87	3.44	65.41	0.5	0.23	0	4.09	9.68	0.37	0.26	0.65	0	0.01		98.37
St.Dev.			0.10	0.24	0.05	0.06	0.01	0.02	0.00	0.03	0.13	0.03	0.03	0.03	0.00	0.00	0.00	0.48
GL 398	II	Group II a	7.69	6.63	4.81	66.67	0.44	0.18	0	1.72	9.73	0.56	0	1.21	0	0.01		99.77
St.Dev.																		
GL 1024	II	Group II a	7.93	6.75	3.7	65.21	0.43	0.27	0	2.63	9.82	0.48	0	0.91	0	0.01		98.33
St.Dev.			0.12	0.70	0.37	0.66	0.05	0.04	0.00	0.04	0.48	0.05	0.00	0.09	0.00	0.01	0.01	0.33
GL 644	II	Group IIIa	5.78	5.02	3.79	66.03	0.39	0.3	0	2.63	11.73	0.54	0.81	0.9	0	0.01		98.11
St.Dev.			4.22	0.15	0.04	1.45	0.03	0.07	0.00	1.09	0.16	0.05	0.05	0.03	0.00	0.01	0.01	3.96
GL 346	II	Group IIIa	6.52	6.55	3.65	68.43	0.49	0.25	0	2.21	10.04	0.55	0	0.86	0	0.01		99.7
St.Dev.			0.33	0.06	0.10	0.05	0.01	0.04	0.00	0.02	0.02	0.02	0.00	0.03	0.00	0.01	0.00	0.34
GL 1649	II	Group IIIa	7.42	5.17	5.45	66.05	0.48	0.18	0	1.99	11.48	0.59	0	1.44	0	0.01		100.45
St.Dev.			0.16	0.08	0.06	0.33	0.01	0.01	0.00	0.02	0.09	0.02	0.00	0.03	0.00	0.01	0.01	0.26

Appendix 2

Table 6.1 EPMA major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Outliers

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 644	II	Group IIIa	7.44	4.57	5.04	66.34	0.48	0.16	0	2.13	12.61	0.58	0	1.21	0	0.01		100.71
St.Dev.			0.22	0.02	0.08	0.12	0.04	0.05	0.00	0.01	0.06	0.06	0.00	0.03	0.00	0.01	0.01	0.29
GL 634	II	Group IIIa	7.72	5.14	3.42	66.14	0.37	0.26	0	2.65	10.42	0.45	0.09	0.95	0	0.02		97.8
St.Dev.			0.63	0.43	0.09	0.56	0.02	0.03	0.00	0.04	0.13	0.02	0.10	0.07	0.00	0.01	0.00	0.88
GL 1405	II	Group IV	7.36	2.85	4.86	66.5	0.35	0.3	0	3.68	7.86	0.1	4.2	0.85	0	0.01		99.27
St.Dev.			0.92	0.02	1.49	0.37	0.02	0.02	0.00	0.03	0.07	0.06	0.24	0.02	0.00	0.01	0.02	1.15
GL 1415	II	Group IV	7.59	2.93	4.13	67.47	0.34	0.28	0	3.75	8.17	0.04	4.52	0.91	0	0		100.36
St.Dev.			0.18	0.05	0.03	0.06	0.03	0.01	0.00	0.02	0.09	0.04	0.07	0.05	0.00	0.01	0.01	0.16
GL 1419	II	Group IV	7.75	2.93	4.03	66.72	0.33	0.29	0	3.59	7.95	0.11	4.49	0.86	0	0		99.29
St.Dev.																		
GL 1397	II	Group IV	7.89	2.9	4.05	66.73	0.33	0.27	0.00	3.65	7.94	0.12	4.48	0.89	0	0.01		99.47
St.Dev.			0.42	0.04	0.08	0.04	0.01	0.01	0.00	0.06	0.06	0.07	0.04	0.02	0.00	0.01	0.00	0.39
GL 1416	II	Group IV	7.89	2.97	4.18	67.62	0.34	0.29	0.00	3.79	8.13	0.04	4.34	0.97	0	0		100.82
St.Dev.			0.21	0.04	0.02	0.11	0.01	0.02	0.00	0.01	0.06	0.02	0.07	0.06	0.00	0.01	0.01	0.27
GL 1392	II	Group IV	7.9	2.94	4.11	66.45	0.32	0.3	0.00	3.77	7.96	0.07	4.42	0.9	0	0.01		99.37
St.Dev.			0.38	0.02	0.03	0.23	0.01	0.01	0.00	0.05	0.04	0.10	0.09	0.03	0.00	0.01	0.00	0.49
GL 1403	II	Group IV	7.93	2.82	3.98	66.07	0.33	0.3	0.00	3.64	7.92	0.07	4.32	0.85	0	0		98.45
St.Dev.			0.28	0.04	0.05	0.07	0.01	0.02	0.00	0.02	0.04	0.13	0.15	0.04	0.00	0.00	0.00	0.19
GL 1399	II	Group IV	7.94	2.93	4.01	66.82	0.33	0.27	0.00	3.75	7.89	0.03	4.5	0.87	0	0.01		99.58
St.Dev.			0.30	0.06	0.05	0.08	0.01	0.03	0.00	0.02	0.05	0.03	0.11	0.00	0.00	0.00	0.02	0.33
GL 735	II	Group IV	7.96	2.94	4.09	67.37	0.33	0.3	0.00	3.75	8.23	0.09	4.74	0.89	0	0		100.89
St.Dev.			0.52	0.03	0.05	0.23	0.02	0.02	0.00	0.05	0.04	0.09	0.05	0.03	0.00	0.00	0.00	0.54

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1396	II	Group IV	7.97	2.93	4.04	66.78	0.34	0.28	0.00	3.72	7.98	0	4.4	0.89	0	0.01		99.51
St.Dev.			0.35	0.04	0.06	0.16	0.02	0.04	0.00	0.02	0.05	0.01	0.13	0.06	0.00	0.01	0.00	0.54
GL 1402	II	Group IV	7.97	2.86	3.99	65.68	0.35	0.27	0.00	3.67	7.8	0.17	4.31	0.85	0	0		98.11
St.Dev.			0.18	0.02	0.02	0.39	0.03	0.02	0.00	0.04	0.09	0.01	0.26	0.04	0.00	0.00	0.00	0.57

Appendix 3

Compositional Data SEM

Table 6.2 SEM major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Based on the compositional errors produced for repeated analysis of Corning standard B in Tables 5.3 and 5.6 the following relative analytical accuracies are associated with the element oxides listed below. Major and minor elements: 3% for Na_2O, 2.5% for SiO_2, 1.5% for K_2O, 1.5% for CaO, 2% for PbO. Minor elements: 5% for MgO, 2.5% for Al_2O_3, 15.5% for P_2O_5, 6.5% for FeO, 5% for CuO and 13% for Cl.

Table 6.2 Chemical composition of glasses from Kadhima, Mughaira and Shiqaya using SEM.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 82			15.05	4.43	4.36	59.97	0.46	0	0	1.69	11.12	0.28	0	1.41	0.00	0.00	0.00	99.37
St.Dev.			0.09	0.10	0.06	0.10	0.05	0.19	0.00	0.04	0.18	0.04	0.00	0.03	0.00	0.00	0.00	0.03
GL 1004			16.12	4	4.13	58.66	0.28	0	0	1.8	10.93	0.26	1.97	1.17	0.00	0.00	0.00	99.31
St.Dev.			0.18	0.09	0.09	0.25	0.06	0.00	0.00	0.04	0.11	0.02	0.04	0.03	0.00	0.00	0.00	0.03
GL 838			15.56	3.3	3.83	60.98	0.41	0.35	0	2.31	9.01	0	2.2	1.33	0.00	0.00	0.00	99.3
St.Dev.			0.42	0.11	0.01	0.19	0.03	0.23	0.00	0.09	0.31	0.16	0.08	0.11	0.00	0.00	0.00	0.02
GL 1062			16.31	4.44	1.84	65.16	0	0	0	2.83	6.95	0	0.51	0.61	0.00	0.00	0.00	99.39
St.Dev.			0.12	0.05	0.04	0.39	0.18	0.21	0.00	0.04	0.09	0.00	0.03	0.04	0.00	0.00	0.00	0.05
GL 1060			15.95	4.02	3.28	63.63	0	0.66	0	2.47	8.34	0	0	1.07	0.00	0.00	0.00	99.42
St.Dev.			0.25	0.05	0.08	0.26	0.00	0.33	0.00	0.02	0.13	0.12	0.00	0.04	0.00	0.00	0.00	0.05
GL 2041			14.35	4.14	4.14	60.29	0.38	0.44	0	2.69	10.48	0	1.07	1.56	0.00	0.00	0.00	99.52
St.Dev.			0.16	0.03	0.14	0.36	0.22	0.21	0.00	0.04	0.04	0.16	0.07	0.03	0.00	0.00	0.00	0.04
GL 773			14.79	3.72	3.24	63.59	0	0	0	2.51	9.09	0	1.36	0.97	0.00	0.00	0.00	99.27
St.Dev.			0.06	0.07	0.05	0.17	0.18	0.16	0.00	0.05	0.15	0.10	0.07	0.03	0.00	0.00	0.00	0.01
GL 210			14.14	3.91	4.04	59.61	0.42	0.43	0	2.72	10.12	0.24	2.59	1.32	0.00	0.00	0.00	99.54
St.Dev.			0.11	0.06	0.02	0.42	0.26	0.22	0.00	0.03	0.05	0.02	0.03	0.06	0.00	0.00	0.00	0.03
GL 1132			15.3	4.15	4.37	59.48	0	0	0	1.6	11.66	0.3	1.19	1.42	0.00	0.00	0.00	99.46
St.Dev.			0.08	0.04	0.07	0.23	0.24	0.24	0.00	0.03	0.03	0.17	0.04	0.09	0.00	0.00	0.00	0.01
GL 732			14.71	2.91	3.19	63.79	0	0	0	2.05	8.69	0.29	2.65	0.93	0.00	0.00	0.00	99.22
St.Dev.			0.14	0.06	0.03	0.33	0.19	0.16	0.00	0.06	0.09	0.13	0.14	0.04	0.00	0.00	0.00	0.03
GL 15			16.37	4.29	1.76	65.35	0	0	0	3.14	7	0	0.78	0.62	0.00	0.00	0.00	99.3
St.Dev.			4.43	3.93	0.48	19.01	0.00	0.20	0.00	0.89	2.05	0.00	1.38	0.07	0.00	0.00	0.00	0.22

Appendix 3

Table 6.2 SEM major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1213			14.53	3.77	3.97	61.96	0.48	0.4	0	2.18	9.75	0.22	1.2	1.11	0.00	0.00	0.00	99.57
St.Dev.			0.21	0.13	0.12	0.17	0.24	0.20	0.00	0.03	0.13	0.03	0.04	0.08	0.00	0.00	0.00	0.05
GL 1234			14.02	3.56	1.05	73.14	0	0	0	1.96	6.07	0	0	0	0.00	0.00	0.00	99.8
St.Dev.			0.15	0.06	0.06	0.19	0.00	0.00	0.00	0.05	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.09
GL 2045			17.08	4.43	1.61	63.98	0	0	0	3.45	7.92	0	0.35	0.44	0.00	0.00	0.00	99.25
St.Dev.			0.18	0.03	0.04	0.22	0.00	0.24	0.00	0.03	0.08	0.00	0.09	0.06	0.00	0.00	0.00	0.01
GL 1674			18.1	6.06	2.44	60.85	0	0.44	0	3.06	7.15	0	0.72	0.76	0.00	0.00	0.00	99.57
St.Dev.			0.17	0.05	0.07	0.11	0.00	0.07	0.00	0.06	0.11	0.00	0.03	0.05	0.00	0.00	0.00	0.04
GL 1114			16.4	5.89	2.4	61.5	0	0	0	4.44	7.69	0	0.52	0.52	0.00	0.00	0.00	99.35
St.Dev.			0.10	0.13	0.07	0.09	0.00	0.00	0.00	0.01	0.12	0.00	0.10	0.06	0.00	0.00	0.00	0.04
GL 778			15.03	3.76	2.79	64.65	0	0	0	2.55	7.52	0.26	1.96	0.76	0.00	0.00	0.00	99.28
St.Dev.			0.24	0.07	0.00	0.21	0.00	0.00	0.00	0.05	0.14	0.13	0.09	0.05	0.00	0.00	0.00	0.03
GL 998			15	3.24	3.42	64.4	0	0	0	2.78	7.5	0	2.04	0.86	0.00	0.00	0.00	99.24
St.Dev.			0.12	0.09	0.02	0.05	0.00	0.00	0.00	0.04	0.10	0.00	0.05	0.06	0.00	0.00	0.00	0.03
GL 651			14.83	4.36	4.41	59.35	0	0	0	1.53	11.32	0.26	1.78	1.42	0.00	0.00	0.00	99.27
St.Dev.			0.14	0.07	0.07	0.13	0.00	0.00	0.00	0.05	0.13	0.15	0.08	0.08	0.00	0.00	0.00	0.04
GL 957			0	1.22	0	1.52	0	2.02	0	0	94.14	0	0	0	0.00	0.00	0.00	100
St.Dev.			0.00	0.61	0.00	40.56	0.00	7.74	0.00	0.00	41.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GL 8			17.24	6.36	1.28	64.26	0	0.47	0	2.6	6.83	0	0	0.33	0.00	0.00	0.00	99.38
St.Dev.			0.13	0.09	0.10	0.13	0.00	0.24	0.00	0.06	0.11	0.00	0.00	0.04	0.00	0.00	0.00	0.08
GL 779			15.16	4.14	3.83	60.66	0	0	0	2.37	10.19	0.2	1.83	1.19	0.00	0.00	0.00	99.57
St.Dev.			0.10	0.09	0.06	0.07	0.00	0.00	0.00	0.07	0.09	0.14	0.05	0.04	0.00	0.00	0.00	0.02

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 559			15.24	4.32	3.54	59.87	0	0.5	0	2.63	11.17	0	1.14	1.21	0.00	0.00	0.00	99.62
St.Dev.			0.24	0.06	0.04	0.19	0.00	0.30	0.00	0.05	0.05	0.16	0.02	0.06	0.00	0.00	0.00	0.05
GL 1844			15.07	4.62	2.13	66.05	0	0	0	3.02	7.02	0	0.8	0.6	0.00	0.00	0.00	99.31
St.Dev.			0.11	0.07	0.10	0.09	0.00	0.00	0.00	0.05	0.03	0.00	0.06	0.07	0.00	0.00	0.00	0.01
GL 1039			16.3	4.83	3.38	60.29	0	0	0	2.55	10.65	0	0	1.04	0.00	0.00	0.00	99.58
St.Dev.			0.09	0.06	0.16	0.04	0.00	0.00	0.00	0.05	0.14	0.00	0.00	0.02	0.00	0.00	0.00	0.04
GL 953			15.24	4.68	2.9	61.95	0.34	0.00	0	3.75	8.79	0	0.46	0.8	0.00	0.00	0.00	99.36
St.Dev.			0.14	0.07	0.12	0.23	0.07	0.00	0.00	0.06	0.14	0.00	0.04	0.08	0.00	0.00	0.00	0.03
GL 1230			16.18	5.56	3.93	60.34	0	0.00	0	2.24	9.97	0	0	1.11	0.00	0.00	0.00	99.31
St.Dev.			0.36	0.03	0.08	0.36	0.29	0.00	0.00	0.06	0.09	0.20	0.00	0.11	0.00	0.00	0.00	0.07
GL 861			16.72	4.75	3.42	59.06	0.41	0.00	0	1.89	11.14	0.26	0	1.08	0.00	0.00	0.00	99.55
St.Dev.			0.19	0.03	0.10	0.44	0.27	0.00	0.00	0.06	0.07	0.17	0.00	0.04	0.00	0.00	0.00	0.04
GL 149			15.69	5.35	3.56	61	0	0.00	0	2.69	9.69	0.25	0	1.12	0.00	0.00	0.00	99.36
St.Dev.			0.38	0.18	0.06	0.34	0.25	0.00	0.00	0.08	0.21	0.13	0.00	0.10	0.00	0.00	0.00	0.05
GL 1335			15.29	3.45	2.7	63.08	0	0.00	0	2.77	7.95	0	2.6	0.93	0.00	0.00	0.00	99.34
St.Dev.			0.28	0.07	0.07	0.25	0.00	0.00	0.00	0.06	0.21	0.00	0.09	0.07	0.00	0.00	0.00	0.06
GL 1364			14.56	4.89	1.85	66.5	0	0.00	0	2.81	5.73	0	2.38	0.73	0.00	0.00	0.00	99.43
St.Dev.			0.05	0.04	0.06	0.35	0.00	0.00	0.00	0.06	0.08	0.00	0.11	0.10	0.00	0.00	0.00	0.04
GL 1329			14.92	4.51	1.79	65.85	0	0.00	0	2.85	6.05	0	2.41	0.61	0.00	0.00	0.00	99.38
St.Dev.			0.12	0.15	0.03	0.13	0.00	0.00	0.00	0.05	0.15	0.00	0.04	0.04	0.00	0.00	0.00	0.03
GL 1351			15.58	3.91	3.2	62.9	0	0.00	0	2.3	10.05	0	0.3	1.04	0.00	0.00	0.00	99.28
St.Dev.			0.17	0.17	0.10	0.24	0.00	0.00	0.00	0.05	0.11	0.18	0.20	0.13	0.00	0.00	0.00	0.06

Appendix 3

Table 6.2 SEM major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 84			15.08	3.97	3.31	63.44	0	0.00	0	2.34	9.8	0	0.33	1.06	0.00	0.00	0.00	99.32
St.Dev.			0.20	0.07	0.11	0.36	0.20	0.00	0.00	0.05	0.17	0.00	0.22	0.08	0.00	0.00	0.00	0.05
GL 1356			14.75	4.87	1.89	66.27	0	0.00	0	2.78	5.56	0	2.17	0.8	0.00	0.00	0.00	99.44
St.Dev.			0.22	0.12	0.13	0.36	0.00	0.00	0.00	0.06	0.19	0.00	0.12	0.09	0.00	0.00	0.00	0.04
GL 1371			14.81	3.85	4.18	62.79	0	0.00	0	2.2	9.32	0	0.7	1.4	0.00	0.00	0.00	99.24
St.Dev.			0.30	0.15	0.17	0.30	0.21	0.00	0.00	0.10	0.16	0.15	0.04	0.03	0.00	0.00	0.00	0.06
GL 989			16.47	5.12	2.53	61.22	0	0.00	0	3.44	9.01	0	0.46	0.75	0.00	0.00	0.00	99.38
St.Dev.			0.13	0.07	0.09	0.23	0.00	0.00	0.00	0.06	0.10	0.00	0.09	0.08	0.00	0.00	0.00	0.06
GL 771			15.3	3.07	2.46	64.2	0	0.00	0	3.22	8.05	0	2.03	1.02	0.00	0.00	0.00	99.36
St.Dev.			0.14	0.09	0.05	0.43	0.00	0.00	0.00	0.07	0.07	0.00	0.16	0.10	0.00	0.00	0.00	0.03
GL 1577			15.68	2.85	2.32	64.15	0	0.00	0	3.11	8.18	0	2.13	0.96	0.00	0.00	0.00	99.39
St.Dev.			0.25	0.09	0.11	0.15	0.00	0.00	0.00	0.04	0.13	0.00	0.08	0.10	0.00	0.00	0.00	0.03
GL 1435			15	2.94	3.13	62.24	0	0.00	0	3.16	9.06	0	2.98	0.84	0.00	0.00	0.00	99.35
St.Dev.			0.18	0.10	0.11	0.26	0.24	0.00	0.00	0.05	0.18	0.00	0.09	0.14	0.00	0.00	0.00	0.03
GL 1302			15.13	2.6	2.54	64.65	0	0.00	0	2.86	8.39	0	2.3	0.79	0.00	0.00	0.00	99.26
St.Dev.			0.37	0.08	0.06	0.26	0.00	0.00	0.00	0.11	0.28	0.00	0.07	0.09	0.00	0.00	0.00	0.06
GL 258			14.4	4.63	4.19	59.9	0	0.00	0	2.65	12.31	0	0	1.54	0.00	0.00	0.00	99.61
St.Dev.			0.27	0.11	0.04	0.31	0.00	0.00	0.00	0.04	0.10	0.18	0.00	0.07	0.00	0.00	0.00	0.06
GL 584			15.23	2.95	2.49	63.17	0	0.00	0	2.9	8.85	0	2.15	1	0.00	0.00	0.00	99.3
St.Dev.			0.07	0.12	0.06	0.70	0.00	0.00	0.00	0.09	0.31	0.00	0.08	0.09	0.00	0.00	0.00	0.04
GL 1007			15.04	3.11	2.16	66.48	0	0.00	0	2.63	7.75	0	1.18	0.94	0.00	0.00	0.00	99.29
St.Dev.			0.10	0.08	0.07	0.11	0.00	0.00	0.00	0.05	0.17	0.00	0.07	0.17	0.00	0.00	0.00	0.05

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1009			15.34	3.02	0	66.3	0	0.00	0	3.16	8.46	0	2.15	0.89	0.00	0.00	0.00	99.32
St.Dev.			0.12	0.14	1.14	1.29	0.20	0.00	0.00	0.07	0.21	0.00	0.16	0.09	0.00	0.00	0.00	0.04
GL 1461			15.61	2.94	2.22	64.23	0	0	0	3.3	8.18	0	1.87	0.95	0	0	0	99.29
St.Dev.			0.19	0.07	0.06	0.15	0.00	0.00	0.00	0.12	0.09	0.00	0.07	0.05	0.00	0.00	0.00	0.03
GL 748			16.05	4.22	2.73	66.31	0	0.00	0	1.98	6.63	0.29	0	0.84	0.00	0.00	0.00	99.05
St.Dev.			0.17	0.14	0.12	0.15	0.00	0.00	0.00	0.03	0.09	0.15	0.00	0.06	0.00	0.00	0.00	0.04
GL 299			14.36	3.19	3.43	64.57	0.39	0.00	0	2.67	9.22	0	0	1.06	0.00	0.00	0.00	99.36
St.Dev.			0.05	0.08	0.08	0.27	0.20	0.00	0.00	0.05	0.12	0.00	0.00	0.06	0.00	0.00	0.00	0.04
GL 1474			15.48	2.87	2.38	64.46	0	0.00	0	3.21	8.01	0	1.99	0.88	0.00	0.00	0.00	99.28
St.Dev.			0.31	0.16	0.05	0.32	0.00	0.00	0.00	0.07	0.17	0.00	0.08	0.10	0.00	0.00	0.00	0.07
GL 1547			14.28	4.73	3.37	64.15	0	0.00	0	2.97	8.28	0	0.33	1.14	0.00	0.00	0.00	99.25
St.Dev.			0.22	0.16	0.03	0.41	0.05	0.00	0.00	0.05	0.06	0.02	0.03	0.05	0.00	0.00	0.00	0.03
GL 80			14.31	4.79	3.25	63.82	0.48	0.00	0	2.94	8.35	0	0.33	0.97	0.00	0.00	0.00	99.24
St.Dev.			0.09	0.10	0.04	0.15	0.07	0.00	0.00	0.05	0.11	0.08	0.06	0.10	0.00	0.00	0.00	0.04
GL 1603			14.77	3.6	3.4	63.81	0	0.00	0	2.54	8.95	0.26	1.03	1.02	0.00	0.00	0.00	99.38
St.Dev.			0.09	0.05	0.04	0.18	0	0.00	0.00	0.03	0.06	0.02	0.07	0.04	0.00	0.00	0.00	0.03
GL 236			14.86	3.73	3.81	62.15	0.52	0.35	0	2.74	9.3	0.26	0.54	1.21	0.00	0.00	0.00	99.47
St.Dev.			0.15	0.05	0.09	0.36	0.08	0.03	0.00	0.04	0.09	0.03	0.01	0.06	0.00	0.00	0.00	0.04
GL 233			14.5	3.97	4.01	62.15	0	0.52	0	2.52	10.12	0.25	0.19	1.43	0.00	0.00	0.00	99.65
St.Dev.			0.25	0.10	0.09	0.21	0.08	0.04	0.00	0.02	0.17	0.06	0.01	0.10	0.00	0.00	0.00	0.05
GL 14			15.68	4.56	4.38	59.72	0.3	0.45	0	2.5	10.22	0.28	0.00	1.51	0.00	0.00	0.00	99.6
St.Dev.			0.16	0.07	0.13	0.18	0.10	0.05	0.00	0.05	0.07	0.04	0.00	0.05	0.00	0.00	0.00	0.03

Appendix 3

Table 6.2 SEM major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1588			15.44	3.38	2.78	63.98	0	0	0	2.42	7.85	0.24	2.26	0.74	0.00	0.00	0.00	99.1
St.Dev.			0.45	0.13	0.08	0.28	0.06	0.05	0.00	0.06	0.11	0.03	0.11	0.05	0.00	0.00	0.00	0.02
GL 1677			15.07	3.23	2.73	64.43	0	0	0	2.51	7.88	0.26	2.31	0.7	0.00	0.00	0.00	99.12
St.Dev.			0.18	0.03	0.03	0.34	0.00	0.00	0.00	0.04	0.10	0.00	0.05	0.02	0.00	0.00	0.00	0.04
GL 1152			15.51	3.14	2.89	63.75	0	0	0	2.95	8.52	0.23	0.76	0.73	0.00	0.00	0.00	99.44
St.Dev.			0.15	0.11	0.07	0.35	0.00	0.11	0.00	0.09	0.14	0.01	0.05	0.04	0.00	0.00	0.00	0.03
GL 218			14.57	3.6	3.17	63.91	0	0.35	0	2.56	8.8	0.25	1.01	1.15	0.00	0.00	0.00	99.37
St.Dev.			0.18	0.07	0.13	0.23	0.00	0.05	0.00	0.05	0.12	0.03	0.08	0.07	0.00	0.00	0.00	0.02
GL 234			15.39	3.28	3.12	63.84	0	0.57	0	3.07	8.53	0	0.91	0.82	0.00	0.00	0.00	99.54
St.Dev.			0.09	0.09	0.07	0.32	0.00	0.05	0.00	0.03	0.13	0.00	0.05	0.03	0.00	0.00	0.00	0.03
GL 1856			14.21	3.41	3.5	64.61	0.4	0.27	0	2.53	9.35	0	0	1.11	0.00	0.00	0.00	99.39
St.Dev.			0.08	0.09	0.05	0.46	0.06	0.02	0.00	0.04	0.14	0.02	0.00	0.03	0.00	0.00	0.00	0.04
GL 83			14.83	3.51	3.28	64.26	0	0	0	2.54	8.69	0.22	1.04	1	0.00	0.00	0.00	99.38
St.Dev.			0.06	0.04	0.06	0.41	0.01	0.00	0.00	0.02	0.14	0.00	0.03	0.05	0.00	0.00	0.00	0.06
GL 1798			13.76	0.67	3.04	73.13	0	0	0	0.76	7.53	0.00	0	0.48	0.00	0.00	0.00	99.37
St.Dev.			0.13	0.03	0.06	0.16	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.05	0.00	0.00	0.00	0.03
GL 1051			13.49	0.61	2.88	73.91	0.00	0.00	0	0.46	7.45	0	0.00	0.5	0.00	0.00	0.00	99.31
St.Dev.			0.28	0.09	0.11	0.20	0.00	0.00	0.00	0.02	0.09	0.00	0.00	0.06	0.00	0.00	0.00	0.03
GL 660			13.92	3.32	3	66.44	0.00	0.00	0	2.42	9.02	0.23	0.00	0.94	0.00	0.00	0.00	99.28
St.Dev.			0.28	0.09	0.11	0.20	0.00	0.00	0.00	0.02	0.09	0.00	0.00	0.06	0.00	0.00	0.00	0.03
GL 1363			14.56	5.02	4.47	59.3	0.36	0.49	0	2.91	10.55	0.31	0.00	1.63	0.00	0.00	0.00	99.59
St.Dev.			0.15	0.06	0.07	0.21	0.00	0.01	0.00	0.04	0.12	0.03	0.00	0.11	0.00	0.00	0.00	0.04

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1848			15.83	6.13	1.22	66.61	0	0.39	0	2.92	4.7	0	1.47	0.23	0.00	0.00	0.00	99.49
St.Dev.			0.34	0.13	0.08	0.24	0.00	0.04	0.00	0.10	0.06	0.00	0.05	0.05	0.00	0.00	0.00	0.02
GL 85			16.5	6.95	1.11	65.54	0	0	0	3.52	4.72	0	0	0.29	0	0	0	99.29
St.Dev.			0.17	0.03	0.05	0.74	0.00	0.00	0.00	0.03	0.03	0	0.00	0.05	0.00	0.00	0.00	0.04
GL 151			15.86	5.48	2.77	63.56	0	0	0	2.68	7.94	0.24	0	0.95	0.00	0.00	0.00	99.47
St.Dev.			0.21	0.16	0.16	0.13	0.00	0.05	0.00	0.04	0.14	0.01	0	0.10	0.00	0.00	0.00	0.05
GL 1077			16.13	4.66	3.57	62.34	0	0	0	2.92	8.55	0	0.23	1.01	0.00	0.00	0.00	99.41
St.Dev.			0.04	0.15	0.05	0.32	0.01	0.04	0.00	0.08	0.19	0	0	0.06	0.00	0.00	0.00	0.06
GL 7			14.57	4.28	4.42	59.96	0.4	0.28	0	1.32	12.48	0	0	1.45	0.00	0.00	0.00	99.16
St.Dev.			0.21	0.07	0.07	0.09	0.06	0.01	0.00	0.06	0.15	0.01	0	0.07	0.00	0.00	0.00	0.06
GL 534			16.01	4	3.74	60.39	0	0.6	0	2.56	10.95	0	0	1.34	0.00	0.00	0.00	99.58
St.Dev.			0.31	0.04	0.08	0.33	0.00	0.09	0.00	0.06	0.11	0.03	0	0.07	0.00	0.00	0.00	0.01
GL 659			15.71	4.25	3.61	60.32	0	0	0	2.37	12.15	0	0	1.21	0.00	0.00	0.00	99.63
St.Dev.			0.29	0.11	0.05	0.21	0.00	0.00	0.00	0.06	0.16	0	0	0.04	0.00	0.00	0.00	0.03
GL 639			17.03	4.66	3.45	60.08	0.00	0.00	0	2.12	10.87	0.21	0	1.11	0.00	0.00	0.00	99.53
St.Dev.			0.19	0.08	0.10	0.22	0.00	0.00	0.00	0.09	0.20	0.06	0	0.06	0.00	0.00	0.00	0.05
GL 1556			14.48	4.39	3.89	60.93	0.00	0.00	0	2.49	11.74	0.3	0	1.26	0.00	0.00	0.00	99.49
St.Dev.			0.13	0.05	0.06	0.18	0.00	0.00	0.00	0.04	0.08	0	0	0.06	0.00	0.00	0.00	0.02
GL 1947			15.2	4.36	4.22	62.12	0.00	0.00	0	2.54	9.38	0.29	0	1.39	0.00	0.00	0.00	99.5
St.Dev.			0.08	0.07	0.05	0.13	0.00	0.00	0.00	0.05	0.02	0.03	0	0.08	0.00	0.00	0.00	0.01
GL 1786			15.7	4.29	4.15	60.35	0.00	0.00	0	2.22	11.09	0.31	0	1.34	0.00	0.00	0.00	99.44
St.Dev.			0.15	0.06	0.07	0.06	0.00	0.00	0.00	0.06	0.10	0.03	0	0.04	0.00	0.00	0.00	0.03

Appendix 3

Table 6.2 SEM major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 152			15.1	4.03	4.15	60.6	0.00	0.00	0	2.35	11.67	0.29	0	1.23	0.00	0.00	0.00	99.41
St.Dev.			0.39	0.09	0.05	0.25	0.00	0.00	0.00	0.08	0.25	0.03	0	0.04	0.00	0.00	0.00	0.04
GL 269			15.56	4.11	4.41	60.74	0.00	0.00	0	2.52	10.22	0.34	0	1.6	0.00	0.00	0.00	99.5
St.Dev.			0.36	0.08	0.09	0.27	0.00	0.00	0.00	0.10	0.16	0.08	0.04	0.05	0.00	0.00	0.00	0.03
GL 1239			16.64	4.76	3.55	59.47	0.00	0.00	0	2.45	11.39	0	0	1.16	0.00	0.00	0.00	99.63
St.Dev.			0.22	0.07	0.11	0.08	0.00	0.00	0.00	0.06	0.30	0.03	0	0.06	0.00	0.00	0.00	0.03
GL 150			15.8	4.77	4.26	60.55	0.00	0.00	0	2.56	9.86	0.29	0	1.49	0.00	0.00	0.00	99.58
St.Dev.			0.27	0.15	0.08	0.26	0.00	0.00	0.00	0.07	0.33	0.02	0	0.09	0.00	0.00	0.00	0.01
GL 61			17.3	5.03	3.05	60.1	0.00	0.00	0	2.58	8.54	0.3	1.42	1.05	0.00	0.00	0.00	99.37
St.Dev.			0.47	0.18	0.07	0.24	0.00	0.00	0.00	0.10	0.32	0	0.09	0.07	0.00	0.00	0.00	0.04
GL 1561			16.13	4.68	4.59	59.94	0.00	0.00	0	2.54	9.97	0.18	0	1.55	0.00	0.00	0.00	99.58
St.Dev.			0.45	0.07	0.16	0.19	0.00	0.00	0.00	0.13	0.31	0.11	0	0.03	0.00	0.00	0.00	0.02
GL 1662			16.14	4.06	3.46	61.11	0.00	0.00	0	2.24	10.65	0	0.7	1.16	0.00	0.00	0.00	99.54
St.Dev.			0.48	0.11	0.15	0.25	0.00	0.00	0.00	0.08	0.42	0	0.03	0.09	0.00	0.00	0.00	0.02
GL 1118			15.27	4.35	4.76	60.47	0.00	0.00	0	1.41	10.9	0.26	0	1.69	0.00	0.00	0.00	99.12
St.Dev.			0.32	0.10	0.03	0.10	0.00	0.00	0.00	0.04	0.21	0.03	0	0.04	0.00	0.00	0.00	0.01
GL 634			15	4.24	3.04	62.65	0.00	0.00	0	2.49	10.19	0	0.6	1.16	0.00	0.00	0.00	99.36
St.Dev.			0.17	0.14	0.16	0.34	0.00	0.00	0.00	0.07	0.22	0	0.13	0.05	0.00	0.00	0.00	0.04
GL 1024			15.53	4.91	3.46	61.96	0.00	0.00	0	2.6	9.79	0	0	1.14	0.00	0.00	0.00	99.39
St.Dev.			0.23	0.17	0.05	0.16	0.00	0.00	0.00	0.14	0.17	0	0	0.08	0.00	0.00	0.00	0.02
GL 1808			14.24	4.62	5.01	58.18	0.00	0.00	0	2.47	12.69	0	0.21	1.84	0.00	0.00	0.00	99.56
St.Dev.			0.48	0.11	0.15	0.25	0.00	0.00	0.00	0.08	0.42	0	0.03	0.09	0.00	0.00	0.00	0.02

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1123			13.44	3.44	3.64	57.48	3.24	0.95	0	2.08	10.32	0	0	1.4	0.00	0.00	0.00	95.98
St.Dev.			0.47	0.28	0.06	3.46	0.00	0.00	0.00	0.16	0.62	0	0	0.04	0.00	0.00	0.00	2.35
GL 138			16.15	3.28	3.28	62.17	0	0	0	3.18	7.76	0.28	2.35	0.86	0	0	0	99.31
St.Dev.			0.12	0.03	0.05	0.15	0.00	0.00	0.00	0.02	0.12	0.05	0.10	0.04	0	0	0	0.05
GL 81			14.19	3.61	3.41	64.09	0	0	0	2.64	9.18	0	1.19	1.12	0	0	0	99.44
St.Dev.			0.20	0.06	0.10	0.29	0.00	0.00	0.00	0.05	0.27	0.01	0.02	0.02	0	0	0	0.03
GL 361			14.56	4.51	4.52	60.57	0	0	0	1.68	11.74	0.24	0	1.65	0	0	0	99.47
St.Dev.			0.02	0.08	0.10	0.10	0.00	0.00	0.00	0.03	0.19	0.04	0.00	0.07	0	0	0	0.08
GL 719			13.49	3.82	4.35	60.17	0	1.82	0	2	11.76	0.29	0	1.51	0	0	0	99.22
St.Dev.			0.40	0.08	0.10	0.77	0.00	0.53	0.00	0.09	0.36	0.05	0.00	0.04	0	0	0	0.02
GL 1323			14.89	4.07	3.52	62.67	0	0	0	2.68	9.35	0.27	0.82	1.19	0	0	0	99.46
St.Dev.			0.16	0.09	0.06	0.18	0.00	0.00	0.00	0.02	0.15	0.02	0.06	0.05	0	0	0	0.04
GL 1761			16.26	4.53	2.86	63.38	0	0	0	2.8	7.88	0.24	0.18	1.14	0	0	0	99.29
St.Dev.			0.33	0.20	0.11	0.33	0.00	0.00	0.00	0.14	0.15	0.02	0.00	0.06	0	0	0	0.14
GL 1944			14.48	4.7	4.85	59.62	0	0	0	2.2	11.75	0	0	1.84	0	0	0	99.43
St.Dev.			0.16	0.06	0.08	0.64	0.00	0.00	0.00	0.03	0.12	0.02	0.00	0.09	0	0	0	0.09
GL 718			17.3	4.19	3.71	60.36	0	0	0	2.29	10.49	0	0	1.15	0	0	0	99.48
St.Dev.			0.21	0.07	0.09	0.17	0.00	0.08	0.00	0.04	0.10	0.03	0.00	0.02	0	0	0	0.02
GL 1599			17.93	4.09	3.77	62.5	0	0	0	2.38	7.33	0	0	1.15	0	0	0	99.15
St.Dev.			0.16	0.13	0.03	0.20	0.00	0.00	0.00	0.06	0.08	0.00	0.00	0.06	0.00	0	0	0.06
GL 725			15.89	3.12	2.85	61.65	0.34	0.62	0	2.9	8.96	0.2	1.83	0.95	0.18	0	0	99.47
St.Dev.			0.17	0.04	0.04	0.19	0.03	0.04	0.00	0.03	0.08	0.01	0.07	0.05	0.04	0	0	0.02

Appendix 3

Table 6.2 SEM major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 986			14.75	3.94	3.98	61.99	0.48	0	0	2.68	9.45	0.24	0.5	1.18	0.18	0	0	99.36
St.Dev.			0.24	0.09	0.05	0.14	0.02	0.00	0.00	0.09	0.18	0.01	0.07	0.06	0.04	0	0	0.01
GL 2068			18.5	4.24	3.77	59.28	0	0	0	2.24	10.26	0.19	0	1.12	0	0	0	99.6
St.Dev.			0.50	0.07	0.03	0.18	0.05	0.00	0.00	0.08	0.20	0.03	0.00	0.07	0.00	0	0	0.02
GL 1652			15.93	3.81	3.7	60.75	0.44	0	0	2.28	9.32	0.23	1.49	1.05	0.21	0	0	99.2
St.Dev.			0.09	0.06	0.03	0.13	0.03	0.00	0.00	0.05	0.12	0.02	0.08	0.04	0.00	0	0	0.05
GL 390			17.54	4.94	4.01	60.93	0.4	0	0	1.51	8.28	0.26	0	1.29	0	0	0	99.17
St.Dev.			0.10	0.06	0.06	0.05	0.03	0.00	0.00	0.04	0.06	0.02	0.00	0.04	0.01	0	0	0.02
GL 854			14.78	3.66	3.42	64.03	0.49	0	0	2.39	8.46	0.18	0.59	1.1	0.2	0	0	99.3
St.Dev.			0.22	0.05	0.05	0.28	0.06	0.00	0.00	0.03	0.13	0.01	0.03	0.04	0.04	0	0	0.01
GL 346			14.91	5.23	3.17	63.3	0.51	0	0	1.92	8.96	0.18	0	0.97	0.17	0	0	99.32
St.Dev.			0.19	0.04	0.06	0.15	0.08	0.00	0.00	0.02	0.09	0.05	0.00	0.02	0.01	0	0	0.03
GL 1649			14.63	3.93	4.72	61.6	0.4	0	0	1.7	10.25	0.29	0.13	1.48	0.14	0	0	99.28
St.Dev.			0.12	0.06	0.01	0.16	0.05	0.00	0.00	0.05	0.09	0.02	0.00	0.07	0.02	0	0	0.02
GL 644			15.44	3.98	3.28	61.17	0.36	0	0	2.81	10.34	0.2	0.91	1	0	0	0	99.48
St.Dev.			0.16	0.08	0.04	0.06	0.06	0.00	0.00	0.05	0.10	0.05	0.03	0.07	0.00	0	0	0.03
GL 1863			14.14	3.62	4.47	61.93	0.43	0	0	1.82	11.11	0.28	0	1.33	0.2	0	0	99.32
St.Dev.			0.20	0.02	0.03	0.11	0.02	0.00	0.00	0.02	0.14	0.04	0.00	0.05	0.02	0	0	0.02
GL 1530			14.66	5.79	3.33	59.5	0.43	0	0	2.92	11.5	0.23	0	1.12	0.19	0	0	99.66
St.Dev.			0.11	0.07	0.02	0.13	0.08	0.00	0.00	0.05	0.08	0.05	0.00	0.04	0.04	0	0	0.02
GL 1995			16.39	4.26	3.15	62.74	0.31	0.43	0	2.76	7.33	0.18	0	1.06	0.18	0.5	0	99.28
St.Dev.			0.27	0.02	0.06	0.31	0.05	0.00	0.00	0.05	0.16	0.01	0.00	0.02	0.04	0	0	0.02
Sample	**Type**	**Group**	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_3**	**ClO**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**FeO**	**Cr_2O_3**	**CuO**	**Zn**	**Total**
GL 396			15	3.99	3.56	60.4	0.33	0.47	0	2.35	10.78	0.19	1.17	1.24	0.16	0	0	99.63
St.Dev.			0.14	0.04	0.06	0.18	0.04	0.03	0.00	0.04	0.19	0.02	0.06	0.04	0.04	0	0	0.03
GL 1263			19.43	3.57	3.37	62.54	0	0	0	1.93	6.95	0.21	0	1.07	0	0	0	99.08
St.Dev.			0.21	0.08	0.02	0.16	0.03	0	0.00	0.05	0.08	0.02	0	0.03	0	0	0	0.02
GL 235			18.07	3.62	2.76	64.23	0.42	0	0	2.1	6.84	0.14	0	1.02	0	0	0	99.2
St.Dev.			0.39	0.05	0.04	0.30	0.01	0	0.00	0.03	0.10	0.02	0	0.06	0	0	0	0.04
GL 721			17.42	3.96	3.16	61.62	0.4	0.43	0	1.15	7.32	0.25	0	1.1	0.19	1.94	0	98.94
St.Dev.			0.16	0.05	0.04	0.42	0.02	0.02	0.00	0.02	0.12	0.02	0	0.01	0	0	0	0.02
GL 1574			14.42	3.38	3.88	63.91	0.41	0	0	2.79	9.04	0.23	0	1.3	0	0	0	99.36
St.Dev.			0.20	0.05	0.04	0.07	0.07	0	0.00	0.03	0.10	0.03	0	0.05	0	0	0	0.02
GL 1556			14.8	4.11	2.42	64.81	0	0	0	2.86	8.1	0.18	1.1	0.8	0.12	0	0	99.3
St.Dev.			0.34	0.10	0.06	0.17	0.09	0	0.00	0.06	0.14	0.01	0.03	0.06	0	0	0	0.04
GL 1264			15.12	3.42	2.07	69.33	0	0	0	2.14	5.47	0	1.12	0.53	0	0	0	99.21
St.Dev.			0.20	0.14	0.03	0.13	0	0	0.00	0.05	0.12	0	0.03	0.04	0	0	0	0.02
GL 1308			14.59	3.64	3.98	64.08	0.51	0	0	2.4	8.67	0.23	0	1.3	0	0	0	99.41
St.Dev.			0.16	0.05	0.07	0.06	0.04	0	0.00	0.03	0.17	0.02	0	0.03	0.04	0	0	0.02
GL 1269			16.34	5.66	2.67	60.13	0	0	0	4.7	8.83	0	0.37	0.66	0	0	0	99.37
St.Dev.			0.08	0.05	0.05	0.13	0	0	0.00	0.02	0.04	0	0.00	0.04	0	0	0	0.02
GL 879			16.07	4.98	1.76	65.21	0	0	0	3.03	6.92	0	0.85	0.55	0	0	0	99.37
St.Dev.			0.13	0.18	0.01	0.15	0	0	0.00	0.05	0.11	0	0.07	0.02	0	0	0	0.03
GL 923			16.01	4.75	1.79	65.38	0	0	0	3.04	7.04	0	0.7	0.53	0.12	0	0	99.35
St.Dev.			0.27	0.13	0.04	0.17	0	0	0.00	0.07	0.14	0.01	0.12	0.04	0	0	0	0.05

Appendix 3

Table 6.2 SEM major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 692			16.28	4.56	1.7	65.59	0	0	0	3.05	6.91	0	0.56	0.54	0.13	0	0	99.31
St.Dev.			0.20	0.24	0.06	0.31	0	0	0.00	0.05	0.13	0	0.15	0.02	0.01	0	0	0.05
GL 1003			15.65	6.22	1.7	64.49	0	0	0	3.89	6.59	0	0.28	0.52	0	0	0	99.33
St.Dev.			0.11	0.07	0.02	0.13	0	0	0.00	0.03	0.07	0	0.03	0.04	0	0	0	0.07
GL 1281			16.31	2.57	2.53	65.51	0	0	0	2.3	8.01	0.15	1.07	0.85	0	0	0	99.3
St.Dev.			0.14	0.02	0.03	0.06	0	0	0.00	0.05	0.12	0.02	0.02	0.04	0.00	0	0	0.04
GL 232			16.29	4.06	3.24	63.08	0	0	0	2.43	8.17	0.17	0	1.1	0	0	0	99.41
St.Dev.			0.22	0.08	0.05	0.33	0	0	0.00	0.09	0.18	0.00	0	0.07	0.01	0	0	
GL 1616			15.19	4.07	4.13	61.72	0.4	0	0	1.93	10.12	0.23	0	1.26	0.21	0	0	99.25
St.Dev.			0.08	0.04	0.07	0.28	0	0	0.00	0.03	0.09	0.01	0	0.02	0.01	0	0	0.02
GL 640			15.43	4.07	3.56	62.47	0	0	0	2.7	9.93	0.2	0	1.15	0	0	0	99.52
St.Dev.			0.10	0.03	0.05	0.30	0	0	0.00	0.02	0.06	0.02	0.04	0.03	0.04	0	0	0.02
GL 1675			16.16	4.43	2.64	62.36	0	0	0	2.79	8.52	0	0.71	1.01	0.13	0	0	99.56
St.Dev.			0.22	0.09	0.09	0.14	0	0	0.00	0.05	0.11	0.01	0.05	0.04	0.04	0	0	0.03
GL 1392			14.69	2.44	3.38	63.42	0	0	0	3.25	7.41	0.17	3.6	0.87	0.13	0	0	99.37
St.Dev.			0.08	0.04	0.09	0.12	0	0	0.00	0.06	0.07	0.02	0.06	0.05	0.03	0	0	0.02
GL 1393			14.83	2.48	3.44	63.26	0	0	0	3.15	7.28	0.19	3.66	0.95	0.13	0	0	99.36
St.Dev.			0.35	0.08	0.02	0.11	0	0	0.00	0.10	0.19	0.01	0.09	0.05	0.01	0	0	0.02
GL 1394			14.45	2.66	3.5	63.32	0	0	0	3.19	7.68	0.19	3.4	1.01	0	0	0	99.4
St.Dev.			0.14	0.08	0.01	0.20	0	0	0.00	0.04	0.10	0.02	0.07	0.02	0.03	0	0	0.03
GL 1395			14.96	2.49	3.46	63.21	0	0	0	3.18	7.15	0.2	3.64	0.91	0.12	0	0	99.34
St.Dev.			0.08	0.01	0.06	0.12	0	0	0.00	0.04	0.05	0.03	0.08	0.06	0.04	0	0	0.01

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1398			15.06	2.55	3.53	63.26	0	0	0	3.14	7.2	0	3.52	0.92	0.18	0	0	99.37
St.Dev.			0.25	0.06	0.06	0.04	0	0	0.00	0.06	0.16	0.03	0.14	0.04	0.01	0	0	0.03
GL 1397			14.97	2.52	3.46	63.31	0	0	0	3.15	7.13	0.19	3.56	0.92	0.17	0	0	99.37
St.Dev.			0.08	0.02	0.06	0.31	0	0	0.00	0.02	0.09	0.03	0.04	0.03	0.01	0	0	0.03
GL 1396			14.6	2.38	3.43	63.45	0	0	0	3.3	7.33	0.19	3.71	0.89	0	0	0	99.29
St.Dev.			0.17	0.05	0.02	0.05	0	0	0.00	0.06	0.09	0.03	0.07	0.05	0.01	0	0	0.03
GL 1399			15.03	2.53	3.42	63.3	0	0	0	3.1	7.17	0.15	3.53	0.95	0.16	0	0	99.34
St.Dev.			0.24	0.09	0.05	0.23	0	0	0.00	0.09	0.14	0.02	0.15	0.04	0.01	0	0	0.01
GL 1400			15	2.53	3.53	63.27	0	0	0	3.17	7.18	0.21	3.48	0.91	0.13	0	0	99.4
St.Dev.			0.09	0.05	0.04	0.07	0	0	0.00	0.05	0.06	0.02	0.09	0.06	0.02	0	0	0.04
GL 149			14.46	2.49	3.38	62.96	0.37	0.37	0	3.26	7.31	0.19	3.59	0.97	0	0	0	99.35
St.Dev.			0.13	0.03	0.23	0.14	0.01	0.04	0.00	0.10	0.08	0.05	0.06	0.06	0	0	0	0.01
GL 1412			14.67	2.46	3.51	63.29	0	0	0	3.19	7.35	0.21	3.6	0.93	0.16	0	0	99.37
St.Dev.			0.35	0.03	0.03	0.16	0	0	0.00	0.04	0.12	0.02	0.04	0.05	0.01	0	0	0.01
GL 1413			14.73	2.53	3.44	63.32	0	0	0	3.15	7.35	0.16	3.58	0.94	0.15	0	0	99.36
St.Dev.			0.21	0.05	0.01	0.02	0	0	0.00	0.07	0.13	0.03	0.08	0.04	0.02	0	0	0.01
GL 1414			14.78	2.56	3.47	63.3	0	0	0	3.21	7.33	0.14	3.55	1.02	0	0	0	99.36
St.Dev.			0.13	0.05	0.03	0.07	0	0	0.00	0.09	0.10	0.04	0.05	0.05	0.04	0	0	0.01
GL 1415			14.18	2.4	3.39	63.19	0.35	0	0	3.25	7.55	0.22	3.75	1.01	0	0	0	99.31
St.Dev.			0.39	0.07	0.08	0.13	0	0	0.00	0.05	0.21	0.01	0.08	0.05	0	0	0	0.03
GL 1418			14.43	2.47	3.47	63.01	0.33	0	0	3.2	7.46	0.26	3.73	0.98	0	0	0	99.34
St.Dev.			0.12	0.03	0.02	0.22	0.03	0	0.00	0.03	0.07	0.04	0.05	0.03	0	0	0	0.02

Appendix 3

Table 6.2 SEM major element compositions of selected glasses from Kadhima, Mughaira and Shiqaya.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1417			14.2	2.39	3.46	63.54	0	0	0	3.31	7.56	0.28	3.67	0.94	0	0	0	99.34
St.Dev.			0.23	0.07	0.03	0.18	0	0	0.00	0.07	0.14	0.03	0.01	0.02	0.01	0	0	0.01
GL 1416			14.7	2.45	3.44	63.28	0	0	0	3.2	7.46	0.22	3.6	0.97	0	0	0	99.32
St.Dev.			0.41	0.05	0.04	0.56	0	0	0.00	0.03	0.40	0.03	0.09	0.04	0	0	0	0.02
GL 1419			15.11	4.1	2.37	66.66	0	0	0	2.86	6.38	0	0.99	0.67	0.15	0	0	99.29
St.Dev.			0.09	0.05	0.05	0.15	0	0	0.00	0.02	0.07	0	0.06	0.05	0.00	0	0	0.02
GL 2142			15.45	3.89	2.21	67.07	0	0	0	2.65	6.26	0.12	0.69	0.8	0.13	0	0	99.27
St.Dev.			0.21	0.05	0.04	0.24	0.00	0.00	0.00	0.06	0.07	0.00	0.03	0.03	0	0	0	0.03
GL 735			14.58	2.41	3.46	62.89	0	0.47	0	3.22	7.3	0.21	3.67	0.92	0.2	0	0	99.33
St.Dev.			0.09	0.03	0.07	0.20	0.00	0.02	0.00	0.03	0.08	0.03	0.04	0.04	0.04	0	0	0.02

Appendix 4

Compositional Data EPMA

Table 6.12 Major element compositions of selected glasses from Unguja Ukuu.

Table 6. 12 Chemical composition of glasses from Unguja Ukuu.

Natron Type

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 2290a	I	Group I	15.33	0.42	2.04	70.02	0.03	0.13	1.07	0.22	9.42	0.22	0.01	0.75	0.02	0.04	0	99.78
St.Dev.			0.15	0.02	0.01	0.81	0.06	0.04	0.03	0.01	0.11	0.02	0.02	0.01	0.01	0.02	0.02	0.73
GL 2290b	I	Group I	15.28	0.39	2.02	68.95	0.04	0.07	1.17	0.23	9.43	0.14	0.03	0.74	0	0.01	0.02	98.54
St.Dev.			0.08	0.06	0.05	1.36	0.03	0.02	0.04	0.01	0.07	0.04	0.01	0.01	0.01	0.01	0.02	1.19
GL 1637	I	Group I	16.97	0.45	2.15	69.31	0.08	0.19	1.21	0.28	8.44	0.23	0	0.82	0	0.04	0	100.25
St.Dev.			0.36	0.02	0.01	0.15	0.09	0.04	0.05	0.03	0.07	0.03	0.01	0.02	0.00	0.03	0.01	0.31
GL 0832	I	Group II	14.72	0.52	2.96	71.05	0.1	0.04	0.92	0.55	7.89	0.07	0.04	0.52	0	0.03	0.01	99.51
St.Dev.			0.19	0.03	0.05	1.13	0.02	0.03	0.04	0.02	0.08	0.02	0.02	0.06	0.02	0.01	0.01	0.97
GL 0765	I	Group II	13.54	0.56	3.04	69.74	0.07	0.03	0.79	0.6	8.73	0.11	0.08	0.58	0	0.01	0.06	98.34
St.Dev.			0.13	0.01	0.03	0.71	0.04	0.02	0.02	0.02	0.09	0.01	0.04	0.05	0.00	0.01	0.03	0.94
GL 0710	I	Group II	13	0.59	2.97	70.72	0.12	0.09	0.82	0.51	10.15	0.07	0.03	0.58	0	0.02	0.04	100.03
St.Dev.			0.15	0.02	0.02	0.17	0.03	0.05	0.05	0.04	0.14	0.01	0.00	0.02	0.01	0.03	0.02	0.11
GL 0764	I	Group II	14.56	0.64	2.96	68.66	0.09	0.04	0.97	0.6	9.32	0.09	0.01	0.45	0.04	0	0	98.49
St.Dev.			0.03	0.04	0.03	0.53	0.04	0.01	0.05	0.00	0.06	0.03	0.02	0.04	0.02	0.02	0.01	0.43
GL 1855	I	Group II	13.58	0.63	2.94	71.39	0.11	0.08	0.88	0.61	8.92	0.07	0.04	0.49	0.01	0.01	0	100.08
St.Dev.			0.10	0.05	0.04	0.61	0.01	0.02	0.03	0.03	0.05	0.01	0.03	0.02	0.01	0.02	0.02	0.71
GL 0712	I	Group II	14.56	0.51	2.87	71.74	0.05	0.07	0.88	0.62	8.27	0.08	0.01	0.46	0	0	0	100.26
St.Dev.			0.09	0.01	0.02	0.93	0.03	0.05	0.01	0.09	0.13	0.01	0.01	0.02	0.01	0.02	0.03	1.03
GL 1999	I	Group II	13.67	0.59	2.98	69.7	0.03	0.06	0.75	0.63	10.11	0.1	0.03	0.56	0	0	0	99.4
St.Dev.			0.16	0.02	0.02	1.55	0.10	0.02	0.03	0.01	0.21	0.03	0.02	0.04	0.01	0.02	0.00	1.40

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 2933	I	Group II	14.29	0.51	2.86	70.66	0.07	0.12	0.84	0.5	8.13	0.05	0.05	0.42	0.01	0.01	0.02	98.7
St.Dev.			0.10	0.03	0.05	0.25	0.04	0.03	0.02	0.02	0.10	0.02	0.00	0.01	0.00	0.01	0.01	0.35
GL 0500	I	Group II	12.4	0.71	3.08	72.19	0.17	0.01	0.83	0.66	9.62	0.09	0.02	0.52	0	0.05	0	100.45
St.Dev.			0.07	0.06	0.03	0.22	0.02	0.01	0.04	0.01	0.09	0.01	0.02	0.03	0.00	0.03	0.01	0.29
GL 3254	I	Group II	0.11	0.03	0.1	23.51	0.04	0.08	0.3	0.04	0.38	0	0	0.08	0.04	0.66	0.03	99.65
St.Dev.			0.02	0.01	0.02	0.80	0.03	0.04	0.03	0.01	0.04	0.02	0.01	0.01	0.02	0.03	0.01	0.43
GL 3386	I	Group II	13.45	0.67	2.99	70.99	0.16	0.12	0.83	0.64	8.8	0.04	0	0.48	0	0.01	0.01	99.31
St.Dev.			0.05	0.04	0.05	0.28	0.05	0.04	0.02	0.03	0.06	0.02	0.03	0.02	0.00	0.00	0.01	0.56
GL 24 12	I	Group II	13.28	0.51	2.86	71.89	0.13	0.03	0.82	0.68	8.56	0.08	0.03	0.4	0	0	0	99.42
St.Dev.			0.05	0.04	0.05	0.52	0.05	0.03	0.04	0.04	0.17	0.02	0.01	0.01	0.02	0.01	0.00	0.61
GL 1770	I	Group II	13.62	0.65	3.1	71.16	0.23	0.04	0.83	0.72	8.17	0.09	0.05	0.53	0.01	0.02	0	99.39
St.Dev.			0.14	0.01	0.01	0.16	0.08	0.02	0.03	0.01	0.02	0.02	0.02	0.01	0.00	0.02	0.01	0.11
GL 0976	I	Group II	12.89	0.56	3.42	72.4	0.01	0.09	0.79	0.44	7.15	0.14	0.04	0.75	0	0	0	98.9
St.Dev.			0.04	0.04	0.27	0.86	0.02	0.04	0.06	0.00	0.45	0.01	0.00	0.20	0.01	0.03	0.02	0.65
GL 2975	I	Group II	12.74	0.59	3.05	73.55	0.02	0.07	0.81	0.52	7.6	0.04	0	0.45	0	0.01	0.02	99.59
St.Dev.																		
GL 0715	I	Group III	13.67	0.66	3.81	69.56	0.05	0.04	0.67	0.86	9.24	0.22	0.02	0.93	0.01	0.01	0.04	99.94
St.Dev.			0.22	0.05	0.48	0.91	0.05	0.00	0.05	0.07	0.26	0.08	0.00	0.23	0.00	0.02	0.01	1.10
GL 0459	I	Group III	12.95	0.57	3.52	73.66	0.08	0.04	0.77	0.47	6.94	0.1	0.03	0.81	0	0.01	0.02	100.1
St.Dev.			0.10	0.01	0.10	0.27	0.00	0.01	0.02	0.01	0.06	0.04	0.01	0.14	0.01	0.02	0.01	0.44

Appendix 4

Table 6.12 Major element compositions of selected glasses from Unguja Ukuu.

Plant-ash Group I

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 3198	II	Group I	13.82	5.72	1.01	68.98	0.12	0.43	0.45	3.53	4.76	0.09	0.08	0.34	0	0	0.04	99.49
St.Dev.			0.03	0.14	0.03	0.45	0.07	0.08	0.03	0.06	0.09	0.02	0.03	0.02	0.02	0.01	0.02	0.34
GL 1638	II	Group I	14.02	5.4	1.04	69.47	0.09	0.28	0.46	3.31	4.4	0.09	0.54	0.4	0.01	0	0	99.93
St.Dev.			0.11	0.01	0.03	0.04	0.04	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.03	0.00	0.00	0.31
GL 0143	II	Group I	15.38	6.45	1.19	66.93	0.07	0.23	0.53	2.86	4.62	0.1	0.15	0.33	0	0	0.01	98.96
St.Dev.			0.01	0.13	0.01	0.46	0.05	0.03	0.02	0.01	0.04	0.01	0.02	0.01	0.02	0.00	0.01	0.30
GL 0949	II	Group I	13.87	4.88	1.5	69.98	0.18	0.26	0.49	3.01	4.43	0.1	0.04	0.45	0.04	0	0.01	99.8
St.Dev.			0.13	0.07	0.02	0.82	0.02	0.04	0.03	0.04	0.01	0.02	0.01	0.02	0.02	0.02	0.00	1.22
GL 1046	II	Group I	15.73	5.43	1.48	66.06	0.13	0.37	0.56	2.97	5.06	0.09	0.58	0.49	0	0	0.04	99.47
St.Dev.			0.75	0.32	0.11	7.31	0.04	0.05	0.06	0.38	0.15	0.02	0.05	0.07	0.02	0.01	0.01	9.45
GL 2616	II	Group I	13.98	5.76	1.44	69.2	0.16	0.32	0.42	2.79	5.17	0.1	0.08	0.49	0	0.03	0.04	100.03
St.Dev.			0.08	0.05	0.03	0.26	0.07	0.04	0.04	0.04	0.07	0.02	0.00	0.03	0.03	0.01	0.02	0.35
GL 0090	II	Group I	14	4.95	1.59	64.58	0.17	0.19	0.56	2.85	5.03	0.11	1.3	1.08	0	0.18	0.27	98.08
St.Dev.			0.10	0.05	0.03	0.66	0.02	0.01	0.04	0.02	0.03	0.01	0.00	0.07	0.00	0.04	0.03	1.21
GL 0470	II	Group I	14.07	3.89	1.61	69.4	0.15	0.14	0.67	3.15	4.61	0.1	0.63	0.63	0	0.02	0.01	99.24
St.Dev.			0.06	0.02	0.03	0.23	0.09	0.01	0.02	0.05	0.02	0.04	0.03	0.04	0.01	0.01	0.03	0.07
GL 0213a	II	Group I	15.16	4.28	1.99	57.83	0.48	0.25	0.78	2.11	5.07	0.29	0.17	3.05	0	2.42	0.01	99.47
St.Dev.			0.17	0.09	0.03	1.01	0.13	0.03	0.03	0.02	0.07	0.06	0.02	0.23	0.01	0.10	0.02	1.16
GL 0213b	II	Group I	16.04	4.28	2.14	64.37	0.75	0.29	0.91	2.14	5.1	0.29	0.08	1.35	0.01	1.91	0	100.11
St.Dev.			0.25	0.15	0.04	1.01	0.19	0.06	0.02	0.07	0.09	0.02	0.03	0.05	0.01	0.52	0.02	0.84
GL 802	II	Group I	15.6	3.33	2.25	64.11	0.36	0.24	0.68	3.15	5.54	0.13	0.04	1.18	0	2.61	0	99.77
St.Dev.			0.12	0.10	0.05	0.75	0.12	0.01	0.00	0.12	0.02	0.01	0.01	0.11	0.01	0.64	0.01	0.37

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 3461	II	Group I	15.84	3.82	1.7	62.04	0.19	0.2	0.76	2.89	6.59	0.16	0.04	2.2	0.01	0.02	0.01	96.8
St.Dev.			0.19	0.07	0.01	0.17	0.04	0.04	0.03	0.04	0.04	0.01	0.02	0.07	0.01	0.01	0.01	0.25
GL 3387	II	Group I	12.5	4.88	1.17	70.54	0.06	0.24	0.63	1.72	6.92	0.05	0.7	0.49	0.03	0	0	100.04
St.Dev.			0.02	0.07	0.02	0.01	0.04	0.01	0.02	0.04	0.09	0.02	0.03	0.03	0.02	0.01	0.01	0.11
GL 382	II	Group I	14.65	3.86	1.19	65.99	0.32	0.2	0.24	2.49	9.33	0.08	0.61	0.54	0.01	0	0.02	100.02
St.Dev.			0.15	0.15	0.13	1.26	0.05	0.04	0.06	0.03	0.07	0.02	0.03	0.05	0.00	0.01	0.01	1.64
GL 1741	II	Group I	13.56	2.22	1.19	66.41	0.31	0.18	0.74	2.71	8.52	0.45	2.05	1.59	0	0	0	99.96
St.Dev.			0.04	0.01	0.01	0.13	0.08	0.01	0.02	0.04	0.11	0.06	0.07	0.03	0.02	0.00	0.01	0.16
GL 1750-	II	Group I	14.75	5.15	1.14	67.87	0.14	0.21	0.63	2.86	3.46	0.07	1.04	0.34	0.01	0	0.04	97.92
St.Dev.			0.10	0.04	0.06	1.20	0.10	0.04	0.01	0.02	0.02	0.02	0.01	0.10	0.02	0.00	0.01	1.19
GL 0889	II	Group I	14.73	5.08	1.23	69.63	0	0.26	0.54	2.66	4.8	0.06	0.05	0.34	0	0.01	0	99.75
St.Dev.			0.31	0.09	0.01	0.43	0.13	0.01	0.04	0.03	0.07	0.03	0.02	0.04	0.00	0.01	0.02	0.32
GL 2980	II	Group I	15.22	4.97	1.4	68.37	0.29	0.39	0.64	3.16	4.52	0.09	0.03	0.49	0.01	0.06	0	100.08
St.Dev.			0.23	0.17	0.03	0.17	0.07	0.06	0.02	0.01	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.47
GL 1853	II	Group I	16.41	5.47	1.29	66.75	0.06	0.2	0.77	2.1	4.28	0.1	1.6	0.46	0	0.02	0.04	99.57
St.Dev.			0.15	0.09	0.02	0.15	0.11	0.04	0.02	0.05	0.09	0.02	0.10	0.03	0.02	0.02	0.02	0.63
GL 1044	II	Group I	14.71	4.04	1.47	70.21	0.21	0.19	0.74	2.78	4.61	0.15	0.19	0.58	0	0.02	0	100.05
St.Dev.			0.19	0.08	0.03	2.05	0.02	0.02	0.02	0.05	0.09	0.03	0.02	0.03	0.02	0.01	0.00	2.14
GL 119	II	Group I	14.43	4.12	1.46	70.63	0.09	0.14	0.69	2.89	4.66	0.13	0.28	0.62	0.02	0.02	0	100.22
St.Dev.			0.17	0.07	0.09	0.15	0.07	0.03	0.01	0.04	0.04	0.02	0.04	0.03	0.01	0.02	0.00	0.18
GL 2723	II	Group I	13.68	5.83	1.59	68.88	0.11	0.22	0.6	2.57	5.41	0.08	0.44	0.51	0.07	0	0.06	100.17
St.Dev.			0.08	0.42	0.09	1.05	0.08	0.02	0.01	0.05	0.35	0.03	0.03	0.02	0.03	0.02	0.03	0.66

Appendix 4

Table 6.12 Major element compositions of selected glasses from Unguja Ukuu.

Plant-ash Group I

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1618	II	Group I	13.36	4.69	1.68	69.79	0.12	0.25	0.49	3.18	5.12	0.09	0.34	0.59	0	0	0.02	99.93
St.Dev.			0.14	0.12	0.02	0.19	0.07	0.04	0.01	0.04	0.08	0.01	0.01	0.04	0.02	0.02	0.01	0.44
GL 0079	II	Group I	14.36	3.89	1.79	69.24	0.37	0.2	0.66	2.87	4.92	0.1	0.34	0.71	0	0.01	0.01	99.48
St.Dev.			0.08	0.07	0.04	0.45	0.04	0.02	0.01	0.06	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.77
GL 1747	II	Group I	14.26	3.98	1.91	69.37	0.26	0.22	0.55	2.98	5.03	0.18	0.24	0.87	0.01	0	0.03	100.31
St.Dev.			0.20	0.09	0.01	0.66	0.04	0.03	0.03	0.01	0.10	0.03	0.06	0.09	0.01	0.01	0.00	0.55
GL 1030	II	Group I	14.52	4.19	1.45	70.43	0.11	0.15	0.7	2.84	4.61	0.03	0.26	0.53	0.02	0	0	100.32
St.Dev.			0.15	0.06	0.03	0.27	0.12	0.01	0.01	0.07	0.05	0.06	0.04	0.06	0.01	0.01	0.03	0.29

Plant-ash Group II

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1950	II	Group II	15.62	4.18	2.16	63.53	0.24	0.15	0.83	3.35	6.63	0.19	0.74	0.93	0.07	0	0.03	99.32
St.Dev.			0.19	0.13	0.03	1.49	0.05	0.02	0.02	0.01	0.05	0.01	0.06	0.03	0.04	0.00	0.02	1.34
GL 1337	II	Group II	15.03	3.64	2.07	64.35	0.3	0.22	0.62	2.96	7.22	0.1	2.65	0.95	0	0	0.04	100.21
St.Dev.			0.15	0.04	0.02	0.50	0.05	0.03	0.03	0.02	0.03	0.03	0.04	0.07	0.02	0.02	0.01	0.66
GL 2846	II	Group II	15.34	4.52	2.11	61.17	0.27	0.16	0.68	2.75	7.48	0.17	0.86	1.5	0.01	0.11	0.29	98.09
St.Dev.			0.09	0.27	0.11	1.04	0.05	0.04	0.03	0.08	0.16	0.03	0.09	0.05	0.01	0.02	0.05	1.28
GL 77	II	Group II	15.92	4.14	2.24	61.46	0.26	0.19	0.67	2.59	7.5	0.12	1.5	0.89	0	0.01	0.05	98.27
St.Dev.			0.09	0.06	0.03	0.55	0.02	0.06	0.02	0.07	0.06	0.02	0.08	0.03	0.00	0.01	0.02	0.68
GL 0904	II	Group II	14.83	2.72	2.16	58.2	0.36	0.3	0.63	3.01	7.81	0.2	3.12	0.9	0	0.04	0.03	94.43
St.Dev.			0.12	0.09	0.03	0.32	0.05	0.04	0.09	0.05	0.06	0.03	0.08	0.04	0.01	0.02	0.00	0.08

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1014	II	Group II	15.02	2.96	2.44	63.71	0.28	0.14	0.7	3.17	6.99	0.14	1.2	0.9	0	0.03	0.05	98.04
St.Dev.			0.17	0.07	0.03	0.46	0.13	0.02	0.02	0.06	0.11	0.01	0.01	0.08	0.02	0.02	0.02	0.78
GL 2857	II	Group II	15.07	4.32	2.46	63.48	0.32	0.26	0.62	2.96	7.13	0.18	0.96	1.47	0	0.1	0.24	99.88
St.Dev.			0.01	0.05	0.05	0.77	0.05	0.04	0.01	0.05	0.13	0.04	0.03	0.06	0.01	0.02	0.02	1.04
GL 2244	II	Group II	15.36	3.63	2.58	62.72	0.24	0.2	0.61	2.99	7.51	0.14	0.14	0.86	0.04	1.69	0.01	99.23
St.Dev.			0.32	0.08	0.11	0.39	0.07	0.02	0.01	0.02	0.38	0.03	0.03	0.09	0.02	0.05	0.00	0.87
GL 659	II	Group II	15.06	3.52	2.77	64.78	0.27	0.14	0.81	1.94	7.36	0.1	1.56	1.02	0	0.03	0	99.75
St.Dev.			0.08	0.06	0.02	0.59	0.08	0.03	0.01	0.03	0.09	0.05	0.04	0.03	0.02	0.01	0.01	0.27
GL 2293	II	Group II	16.59	3.55	2.76	57.94	0.29	0.27	0.33	2.42	7.99	0.19	2.43	1.03	0.01	0.03	0.01	96
St.Dev.			0.29	0.02	0.02	0.86	0.03	0.01	0.26	0.02	0.09	0.05	0.05	0.03	0.01	0.02	0.02	0.09
GL 2715	II	Group II	15.47	3.33	2.73	62.11	0.35	0.18	0.65	2.23	9.22	0.2	1.98	0.96	0.01	0.05	0.01	99.86
St.Dev.			0.08	0.03	0.04	0.18	0.04	0.04	0.02	0.01	0.04	0.03	0.09	0.02	0.01	0.02	0.01	0.31
GL 572	II	Group II	15.17	3.06	2.78	62.97	0.26	0.25	0.59	2.95	8.91	0.21	1.35	0.92	0	0.01	0	99.98
St.Dev.			0.06	0.14	0.04	0.11	0.05	0.04	0.02	0.06	0.17	0.02	0.04	0.03	0.01	0.00	0.02	0.40
GL 3338	II	Group II	14.45	3.58	2.96	63.68	0.39	0.22	0.72	2.21	8.45	0.15	1.37	1.01	0.02	0	0	99.31
St.Dev.			0.05	0.11	0.04	0.43	0.04	0.03	0.07	0.06	0.06	0.00	0.01	0.03	0.00	0.01	0.00	0.81
GL 2657	II	Group II	15.43	3.69	3.1	62.37	0.44	0.2	0.78	2.45	8.85	0.2	0.49	1.2	0.01	0.03	0	99.61
St.Dev.			0.12	0.07	0.02	0.53	0.07	0.03	0.04	0.05	0.06	0.02	0.02	0.07	0.00	0.02	0.00	0.67

Appendix 4

Table 6.12 Major element compositions of selected glasses from Unguja Ukuu.

Plant-ash Group II

Sample	*Type*	*Group*	*Na_2O*	*MgO*	*Al_2O_3*	*SiO_2*	*P_2O_5*	*SO_3*	*ClO*	*K_2O*	*CaO*	*TiO_2*	*MnO*	*FeO*	*Cr_2O_3*	*CuO*	*Zn*	*Total*
GL 0717	II	Group II	12.32	0.62	3.11	70.68	0.11	0.07	0.67	1.13	8.86	0.06	0.01	1.71	0.01	0	0	99.65
St.Dev.			0.05	0.03	0.05	0.19	0.07	0.02	0.03	0.09	0.35	0.01	0.01	0.26	0.01	0.03	0.00	0.55
GL 0757 a	II	Group II	15.01	3.48	3.26	62.49	0.25	0.35	0.47	2.27	9.27	0.2	1	1.01	0.03	0	0	99.09
St.Dev.			0.25	0.06	0.01	0.30	0.03	0.04	0.03	0.04	0.06	0.02	0.03	0.10	0.02	0.01	0.00	0.52
GL 0757 b	II	Group II	15.09	3.33	3.26	62.65	0.32	0.33	0.5	2.37	9.36	0.18	0.96	0.86	0.05	0.01	0	99.87
St.Dev.			0.10	0.20	0.08	0.55	0.03	0.06	0.02	0.05	0.15	0.02	0.07	0.05	0.01	0.02	0.00	0.38
GL 2689	II	Group II	15.17	3.83	3.12	61.85	0.32	0.21	0.58	2.51	9.73	0.2	0.43	1.21	0.03	0.04	0	99.43
St.Dev.			0.34	0.07	0.04	0.47	0.04	0.02	0.04	0.03	0.14	0.05	0.06	0.05	0.01	0.02	0.01	0.54
GL 3145	II	Group II	15.66	4.35	2.99	59.27	0.34	0.2	0.45	2.13	10.06	0.16	0.94	1.14	0	0	0	98.43
St.Dev.			0.19	0.05	0.02	0.09	0.00	0.02	0.06	0.01	0.03	0.01	0.06	0.02	0.01	0.00	0.00	0.57
GL 1633	II	Group II	14.84	3.53	3.27	62.87	0.49	0.13	0.85	2.35	7.93	0.2	1.91	1.1	0	0	0.07	99.69
St.Dev.			0.14	0.11	0.03	0.49	0.02	0.01	0.01	0.04	0.19	0.07	0.15	0.11	0.01	0.00	0.03	0.43
GL 1626	II	Group II	16.5	3.42	2.06	64.67	0.18	0.16	0.91	1.96	7.33	0.12	1.16	0.59	0.04	0.01	0.03	99.82
St.Dev.			0.02	0.06	0.02	1.48	0.05	0.02	0.04	0.04	0.09	0.03	0.03	0.03	0.02	0.02	0.01	1.32
GL 2147	II	Group II	15.41	3.92	2.4	63.54	0.33	0.24	0.7	2.91	8.62	0.26	0.03	1.05	0	0	0.04	99.51
St.Dev.			0.03	0.07	0.05	0.20	0.16	0.01	0.03	0.05	0.08	0.04	0.03	0.04	0.02	0.00	0.02	0.50
GL 2325	II	Group II	15.9	3.29	3.28	60.43	0.3	0.21	0.79	2.62	8.66	0.28	2.12	1.07	0.03	0	0.02	99.36
St.Dev.			0.20	0.06	0.04	0.42	0.17	0.03	0.08	0.05	0.18	0.05	0.02	0.04	0.01	0.01	0.01	0.59
GL 2677	II	Group II	15	4.45	2.49	63.27	0.28	0.27	0.65	2.91	7.25	0.19	1.03	1.36	0.04	0.04	0.21	99.65
St.Dev.			0.18	0.06	0.03	0.60	0.09	0.04	0.03	0.05	0.07	0.03	0.07	0.07	0.02	0.04	0.03	0.53
GL 0911	II	Group II	15.97	4.24	2.87	60.96	0.32	0.28	0.73	2.49	9.79	0.18	0.7	1.07	0.07	0.03	0.01	100.11
St.Dev.			0.23	0.09	0.03	0.17	0.06	0.03	0.04	0.00	0.03	0.02	0.03	0.06	0.03	0.01	0.01	0.45

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1343	II	Group II	15.32	4.09	3.24	60.37	0.41	0.36	0.51	2.31	10.21	0.17	1.63	1.22	0.05	0.02	0.04	100.05
St.Dev.			0.20	0.11	0.01	0.17	0.07	0.04	0.01	0.03	0.07	0.06	0.05	0.04	0.03	0.00	0.00	0.33
GL 0190	II	Group II	14.61	2.79	2.32	64.59	0.26	0.11	0.73	3.18	6.99	0.14	1.27	0.94	0	0	0.04	98.61
St.Dev.			0.15	0.02	0.01	0.70	0.08	0.03	0.02	0.03	0.05	0.03	0.01	0.03	0.02	0.00	0.02	0.81
GL 2450	II	Group II	15.42	4.74	2.58	60.27	0.35	0.15	0.83	2.01	8.81	0.17	1.62	1.1	0.06	0.01	0	98.35
St.Dev.			0.12	0.08	0.06	0.16	0.09	0.05	0.01	0.07	0.09	0.02	0.03	0.04	0.02	0.01	0.01	0.70
GL 2097	II	Group II	14.81	4.22	2.56	63.53	0.45	0.15	0.61	2.79	7.14	0.13	1.04	1	0	0.02	0.04	99.14
St.Dev.			0.10	0.19	0.04	1.00	0.15	0.03	0.03	0.10	0.15	0.01	0.19	0.01	0.01	0.01	0.01	1.25
GL 1339	II	Group II	15.09	3.68	2.44	62.55	0.36	0.18	0.71	2.69	7.36	0.13	1.55	0.98	0	0.08	0	97.89
St.Dev.			0.14	0.22	0.06	0.93	0.05	0.02	0.05	0.01	0.11	0.03	0.23	0.04	0.00	0.04	0.01	1.15
GL 0155	II	Group II	14.99	2.63	2.13	64.4	0.24	0.2	0.79	2.77	7.17	0.18	2.72	0.92	0	0	0	99.46
St.Dev.			0.23	0.04	0.03	0.30	0.03	0.01	0.02	0.03	0.05	0.01	0.06	0.07	0.00	0.00	0.02	0.14
GL 3450	II	Group II	14.61	3.72	2.62	63.13	0.45	0.2	0.75	2.58	8.26	0.11	2.05	0.93	0.03	0	0.02	99.95
St.Dev.			0.10	0.11	0.08	0.14	0.11	0.05	0.03	0.03	0.02	0.06	0.05	0.07	0.01	0.00	0.00	0.23
GL 0040	II	Group II	14.16	3.28	2.42	61.08	0.44	0.17	0.32	2.69	10.3	0.2	0.81	1.91	0.01	0.17	0.51	98.86
St.Dev.			0.41	0.12	0.04	0.49	0.10	0.07	0.11	0.07	0.08	0.05	0.06	0.11	0.01	0.01	0.05	0.35
GL 0154	II	Group II	14.47	2.69	2.14	64.6	0.33	0.21	0.7	2.76	7.21	0.14	2.74	0.99	0.02	0	0.02	99.53
St.Dev.			0.06	0.09	0.02	0.17	0.08	0.04	0.07	0.05	0.13	0.03	0.13	0.07	0.01	0.01	0.01	0.61
GL 0038	II	Group II	15.04	2.53	2.18	65.1	0.44	0.22	0.79	2.96	6.63	0.19	2.75	0.85	0.01	0.03	0.01	99.93
St.Dev.			0.47	0.08	0.05	0.38	0.06	0.01	0.02	0.07	0.07	0.02	0.04	0.02	0.02	0.02	0.01	0.92
GL 3449	II	Group II	14.77	3.66	2.62	63.21	0.27	0.14	0.73	2.54	8.34	0.16	2.09	0.9	0.01	0.02	0.02	99.72
St.Dev.			0.18	0.03	0.01	0.13	0.02	0.06	0.02	0.00	0.12	0.01	0.13	0.06	0.02	0.01	0.01	0.25

Appendix 4

Table 6.12 Major element compositions of selected glasses from Unguja Ukuu.

Plant-ash Group II

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 0635	II	Group II	14.77	3.93	2.43	63.13	0.34	0.2	0.65	2.48	7.7	0.13	2.35	0.99	0	0.02	0.06	99.56
St.Dev.			0.05	0.08	0.02	0.01	0.02	0.01	0.02	0.05	0.14	0.03	0.07	0.05	0.03	0.02	0.03	0.43
GL 0943	II	Group II	15.07	4.2	2.57	62.62	0.13	0.2	0.6	2.78	7.64	0.11	2.04	0.81	0	0.04	0.02	98.96
St.Dev.			0.05	0.01	0.03	0.62	0.11	0.03	0.03	0.01	0.08	0.05	0.01	0.08	0.02	0.02	0.01	0.75
GL 1029	II	Group II	15.07	4.23	2.69	62.91	0.32	0.25	0.62	3.2	7.8	0.17	0.85	1.04	0.08	0.06	0	99.47
St.Dev.			0.07	0.11	0.05	0.41	0.01	0.05	0.01	0.07	0.07	0.03	0.03	0.01	0.05	0.03	0.03	0.48
GL 1620	II	Group II	13.17	0.58	3.11	72.27	0.12	0.06	0.75	0.6	8.26	0.07	0.03	0.94	0	0	0.04	100.1
St.Dev.			0.15	0.04	0.06	0.67	0.04	0.02	0.04	0.02	0.16	0.02	0.02	0.27	0.01	0.01	0.01	0.69
GL 2975	II	Group II	12.74	0.59	3.05	73.55	0.02	0.07	0.81	0.52	7.6	0.04	0	0.45	0	0.01	0.02	99.59
St.Dev.			0.09	0.03	0.01	0.33	0.02	0.03	0.03	0.03	0.02	0.02	0.01	0.06	0.00	0.00	0.01	0.35

Plant-ash Group III

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 2478	II	Group III	14.57	3.73	3.48	60.12	0.3	0.28	0.45	2.97	10.84	0.23	0.07	1.3	0.03	0	0.01	98.62
St.Dev.			0.10	0.13	0.08	0.86	0.06	0.03	0.07	0.06	0.15	0.04	0.04	0.03	0.02	0.00	0.00	1.25
GL 201	II	Group III	15.19	4.03	3.62	56.95	0.25	0.32	0.44	2.47	10.36	0.16	1.02	1.43	0.03	0.01	0.02	96.47
St.Dev.			0.24	0.05	0.06	1.18	0.10	0.02	0.01	0.03	0.14	0.03	0.06	0.06	0.01	0.00	0.02	1.41
GL 2455	II	Group III	15.01	4.05	3.66	60.19	0.42	0.28	0.5	2.37	10.37	0.2	0.56	1.43	0.01	0.02	0	99.31
St.Dev.			0.16	0.08	0.01	0.84	0.06	0.03	0.01	0.04	0.17	0.02	0.02	0.04	0.01	0.03	0.01	0.63
GL 2981	II	Group III	14.92	4.24	3.71	61.89	0.5	0.18	0.73	1.94	10.13	0.24	0.04	1.43	0.04	0.01	0.04	100.2
St.Dev.			0.22	0.02	0.09	0.43	0.02	0.02	0.04	0.02	0.06	0.04	0.02	0.11	0.01	0.01	0.03	1.00

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 3306	II	Group III	15	4.12	3.74	59.95	0.41	0.19	0.45	1.98	10.1	0.21	1.14	1.55	0.01	0.02	0.05	99.42
St.Dev.			0.35	0.03	0.02	0.63	0.01	0.05	0.05	0.03	0.12	0.01	0.03	0.05	0.01	0.01	0.05	0.60
GL 3257 a	II	Group III	15.16	3.85	3.75	58.2	0.28	0.38	0.37	2.57	10.59	0.23	1.87	1.28	0.02	0	0.04	98.81
St.Dev.			0.11	0.03	0.05	0.14	0.09	0.03	0.04	0.04	0.07	0.03	0.03	0.07	0.01	0.04	0.02	0.26
GL 3257 b	II	Group III	14.46	3.79	3.79	56.59	0.4	0.4	0.34	2.55	10.7	0.2	2.33	1.58	0.04	0.04	0	97.53
St.Dev.			0.06	0.10	0.12	0.05	0.05	0.06	0.03	0.03	0.18	0.01	0.05	0.03	0.02	0.03	0.02	0.01
GL 657	II	Group III	16.23	4.18	4.34	54.71	0.37	0.39	0.31	2.76	10.28	0.24	0.08	1.75	0.03	0.02	0	95.85
St.Dev.			0.28	0.05	0.03	0.35	0.07	0.02	0.06	0.03	0.26	0.03	0.02	0.08	0.01	0.01	0.01	0.65
GL 0984 a	II	Group III	14.1	4.32	4.51	58.35	0.54	0.36	0.35	2.83	10.89	0.25	0.11	1.84	0	0.02	0.01	98.85
St.Dev.			0.11	0.14	0.04	0.37	0.11	0.03	0.03	0.04	0.07	0.01	0.05	0.16	0.04	0.01	0.02	0.21
GL 0984 b	II	Group III	13.97	4.76	4.54	59.29	0.39	0.39	0.28	2.74	10.96	0.32	0.07	1.58	0	0.01	0	99.68
St.Dev.																		
GL 2580	II	Group III	15.94	3.92	3.61	59.91	0.41	0.23	0.77	1.71	10.07	0.18	1.33	1.28	0.02	0.01	0.02	99.48
St.Dev.			0.09	0.08	0.02	0.08	0.11	0.04	0.02	0.03	0.09	0.03	0.08	0.02	0.02	0.01	0.04	0.78
GL 2978	II	Group III	14.97	3.39	3.5	60.05	0.22	0.3	0.61	2.44	10.95	0.18	0.02	1.32	0.07	0	0.02	98.15
St.Dev.			0.11	0.07	0.01	0.91	0.08	0.05	0.03	0.03	0.17	0.04	0.01	0.05	0.02	0.02	0.02	1.11
GL 2403	II	Group III	15.2	4.29	3.67	60.32	0.32	0.23	0.79	1.52	11.1	0.25	0.11	1.52	0.02	0.03	0.02	99.45
St.Dev.			0.10	0.14	0.09	0.98	0.10	0.02	0.02	0.02	0.16	0.01	0.01	0.03	0.01	0.01	0.02	1.20
GL 2522	II	Group III	15.44	3.98	3.85	57.76	0.31	0.14	0.91	1.47	10.9	0.2	0.07	1.57	0.01	0.01	0.02	96.7
St.Dev.			0.21	0.09	0.07	1.01	0.03	0.03	0.08	0.03	0.24	0.04	0.02	0.42	0.01	0.00	0.01	1.25
GL 2475	II	Group III	15.14	4.35	3.89	58.82	0.42	0.25	0.64	2.33	10.31	0.21	0.85	1.57	0.02	0.04	0.01	98.98
St.Dev.			0.08	0.02	0.03	0.16	0.05	0.02	0.02	0.05	0.00	0.04	0.03	0.06	0.03	0.02	0.02	0.16

Appendix 4

Table 6.12 Major element compositions of selected glasses from Unguja Ukuu.

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 1750	II	Group III	13.69	3.79	4.3	60.23	0.51	0.38	0.28	2.96	9.92	0.25	0.04	1.66	0.02	0	0.01	98.33
St.Dev.			0.04	0.09	0.05	2.54	0.06	0.03	0.03	0.02	0.08	0.03	0.01	0.09	0.04	0.00	0.03	3.07

Plant-ash Group IV

Sample	Type	Group	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Cr_2O_3	CuO	Zn	Total
GL 3255	II	Group IV	14.87	3.52	3.92	60.46	0.56	0.18	0.7	1.99	8.15	0.32	2.43	1.23	0.04	0	0	98.5
St.Dev.			0.09	0.15	0.07	1.35	0.05	0.04	0.05	0.02	0.10	0.04	0.06	0.07	0.02	0.01	0.01	1.31
GL 2100	II	Group IV	14.29	2.76	3.7	62.6	0.28	0.16	0.82	1.6	7.99	0.26	4.03	1.27	0	0	0.03	99.98
St.Dev.			0.17	0.01	0.03	0.44	0.14	0.01	0.12	0.01	0.04	0.01	0.04	0.04	0.04	0.01	0.02	0.35