The Early Islamic Glass from Sir Bani Yas, U.A.E.

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Summary

Detailed studies of the pottery and stuccoes of the church and associated complex at Sir Bani Yas indicate these date to the seventh and eighth centuries. This paper examines the only other significant set of finds, namely the glassware. Several other churches and monasteries have been excavated in the Persian Gulf and Western Desert of Iraq but this is the first occasion where the glass assemblage has been studied in detail and has included comprehensive scientific analysis of the glass compositions. Analysis by electron probe microanalysis of 85 samples has identified four compositional groups. The largest is relatively high in lime and alumina, and could not be related to previously analysed groups. Two groups were compositionally similar to Mesopotamian glass of the Sasanian and early Islamic periods, corresponding to Mesopotamian Types 1 and 2 of Phelps (2016) and suggest trade in glass from Mesopotamia to Sir Bani Yas. A final group is small and shares similarity to three contemporary samples from Kush. The sparse use of MnO as a decolourant in the glass as opposed to its ubiquitous use in 9th century Abbasid glass suggests an Early Islamic seventh-eighth century date for this assemblage, consistent with the ceramic dating.

Keywords: Sir Bani Yas, electron microprobe analysis, glass, early Islamic, church

Introduction

The island of Sir Bani Yas is located in the lower part of the Persian Gulf, nine kilometres offshore from Jabal Dhannah on the Abu Dhabi coast of the United Arab Emirates (Fig. 1). An archaeological survey of the island was carried out in April 1992 as part of the Abu Dhabi Islands Archaeological Survey [ADIAS], and among the recorded sites was a small cluster on the eastern side, some 700 metres west of the sheltered lagoon of al-Khawr, and designated SBY 3–9 (King 1998: 20–27). This spot would have served as a natural harbour and been suitable for quiet fishing attested by the remains of shallow-water fish recovered from the excavations which followed between 1993 and 1996 (Beech 2004: 110–21, 182). The largest of these sites proved to be the collapsed remains of a small church constructed of rubble and mortar which was originally decorated in places with moulded stuccoes (King & Hellyer 1998). The building was soon interpreted as belonging to a pre-Islamic Nestorian monastery, the other structures regarded as outbuildings and cells for the community and the complex dated to the sixth and seventh century (King 1997; King & Hellyer 1998; Hellyer 2001; Elders 2001; Elders 2003).

This date put the site into the political context of the Persian Church of the Sasanian empire in a region where there is little evidence for sedentary occupation at this period and many, if not all, of the other churches and monasteries excavated within the Persian Gulf and southern Iraq instead date, according to the associated finds, to the late seventh to early ninth centuries. It is during the latter period that there is evidence for increasing sedentarisation across eastern Arabia and the Persian Church was actively expanding in this area (Bin Seray 1996; Carter 2008a; De Langhe 2008; Payne 2011; Simpson 2018). Consequently the exact date of the Sir

Bani Yas has attracted renewed scrutiny. The only absolute dates are two radiocarbon dates which were obtained from the same charcoal sample taken from a small hearth in a building near the church which was sealed by a collapsed wall and thought to represent a good *terminus ante quem* for the abandonment of the complex (Elders 2001: 56). One conventional c14 date (GU-9185) and one AMS date (AA-40740) were run and yielded dates of 1460±70 BP (calibrated as AD 420–670 at 93% probability) and 1305±50 BP (calibrated as AD 640–830 at 95% probability) respectably. As both were from the same sample they can be combined and this gives a date of 1358±41 BP (calibrated as AD 740–770 at 95.4% probability), although questions still remain over whether the age of the wood or whether the hearth was post-occupational. The eighth century date of abandonment is supported by a detailed study of the pottery as there are no known types of Sasanian pottery, either local or imported, and the assemblage most closely resembles that from period III at the site of Kush, in Ras al-Khaimah, which is dated to the eighth century (Kennet 2007: 89–94; Carter 2008b). Although previous studies have suggested late Sasanian parallels for some of the stuccoes, they are most similar to those from the eighth century site of Tulul al-Ukhaidhir in the Iraqi Western Desert and independent studies by Lic (2017) and Simpson (2018) have argued a similar date for Sir Bani Yas. There are few other finds apart from the glassware and this is presented in detail here for the first time.

Fig. 1 near here

The assemblage

This report is the first analysis of the glass from Sir Bani Yas, although a preliminary report noted the presence of “pieces of fine glass vessels, including a nearly complete small drinking cup” (King & Hellyer 1998: 47), and a more recent study of the pottery (Carter 2008b: 90–91) cited the observation by one of the present authors (Simpson) that the glass assemblage appeared to be best paralleled with Umayyad assemblages. The quantification and typological comparanda are the work of Simpson; the glass was sampled for scientific analysis and this research was carried out at UCL by Phelps and Freestone.

Quantification and spatial distribution

A total of 237 glass sherds were recorded, of which 67.5% were from the church-site of SBY-9, and the remainder from the outlying buildings which were separately numbered as SBY-2, SBY-4 and SBY-7. The sandy deposits covering the church and outlying buildings produced 18 and 5 glass sherds respectively but this deposit was heavily disturbed by bulldozing associated with modern landscaping of the area and was excavated by shovel. The excavation technique of other contexts to produce glassware sherds is not always recorded but varied from shovel to trowel. Sieving is recorded in several instances (ctx 170, 173, 201, 210, 212), but as only 13 glass sherds were recovered from these contexts it does not appear to have led to significantly higher recovery, probably because the predominantly sandy matrix of the site deposits enabled relatively easy identification of glass. Most excavated contexts produced a maximum of 3 sherds and many failed to yield any glass at all. Slightly larger quantities were found in the enclosure surrounding the church, namely ctx 115 (rubble = 8 sherds) and ctx 170 (7 sherds), but the largest concentration came from ctx 125, one of the areas of collapsed walling of the church (55 sherds). This was also one of the richest pottery-producing contexts according to Carter’s (2008) analysis. The most significant contexts to produce glass within the church are ctx 131, a sandy deposit within the south aisle, which yielded 23 sherds (compared to 128 sherds of pottery) and 150, described as the partition wall between north aisle or transept and the nave, which produced 24 sherds (compared to 51 potsherds). The first of these contexts was also the most significant pottery-producing context inside the church (Carter 2008b). Although the site stratigraphy was shallow and partly disturbed, no obviously intrusive fragments were recognised in this analysis and there appears to be a good match between contexts producing pottery and glass, although the reasons behind this spatial pattern are unclear. The implications are clear that if the pottery and glass are of the same date, then this provides a stronger argument for the dating of the occupation of the complex.

Summary of the assemblage

All of the glass was free blown and there is no evidence for the use of moulds. The commonest form was a straight-sided bowl with thin undecorated walls, often with an infolded or fire-polished rim (1201b, 1252b, 1258a, 1299, 1480b, 1481d, G.7a), and sherds of these were found at SBY-2, SBY-7 and SBY-9. The rims and/or shoulders of small jars were the second most common form and were found at the same range of sites (1201c, 1234a, 1248, 1418a, 1420c, plus possibly 1166, 1480i, 1481b). Three rims belonged to other bowl forms, including a hemispherical bowl (1480f), an open bowl with a rim diameter of 22 cm (1480a) and another of uncertain type (1167). A partially reconstructed juglet was found in the church (1447). Two small bottles or flasks with cylindrical necks were represented by rims which had been pulled out, folded back and pushed flat along the top, creating a heavily reinforced thickened top to the vessel (1417a, 1420a). One other rim could not be assigned to a vessel shape (1419a). A semi-complete stemmed goblet was found in the church (1249a), and possible fragments of two others were found at SBY-7 and SBY-9 (1180a, 1421a). 16 other bases belonged to small vessels with low push-ups of between 0.5 and 0.8 cm height (1184, 1201a, 1243, 1244a, 1260, 1320, 1418b, 1419b, 1421b, 1483, 1487), and others had the impressed traces of hollow pontils measuring between 0.6 and 2.5 cm across (1228, 1246a, 1269, 1480c); in one other case an irregular facet had removed any traces of a pontil (1225a). It is not certain what these bases belonged to as they could have belonged either to open or closed forms. Apart from a single bottle with a cylindrical neck which was decorated with single trails applied around the upper body, and a thicker wavy trail applied between and overlapping the earlier trails (1298), all of the glass is plain and undecorated. Two possible tubular spouts (1423, 1425), an applied lug (1201d) and an applique blob (1252c) represent the only other diagnostic elements. A catalogue of the analysed samples is provided in Appendix A.

Comparative analysis

Sasanian glass is relatively well understood in terms of the range of shapes, production techniques and styles of decoration (Simpson 2014). Fragments have been found in Period I and II contexts at Kush in Ras al-Khaimah (Keller forthcoming; Fig. 1) and small numbers of complete beakers and bowls are known from graves in the Eastern Province of Saudi Arabia, Bahrain and the Batinah coast of Oman (Zarins et al. 1984, 42, pl. 50.10; Andersen 2007). None of these types were found at Sir Ban Yas and instead the closest parallels come from the occupation site of Jazirat al-Hulayla in Ras al-Khaimah which is well dated by the pottery to the seventh–eighth centuries (Kennet 1994). It is during the early Islamic period that there appears to be an increase in glass vessel production, including Iran and Central Asia for the first time, and there are new compositions as well as new colours, forms and styles of decoration. There is little quantification of the glass from these sites but Adams (1970: 114) remarked that "the intensity of glass was conspicuously the highest" in level IV in the sequence at Tell Abu Sarifa, which he considered to date to the seventh/eighth century. At Jazirat al-Hulayla the total number of sherds of glassware is not recorded in the publications but the range of forms appears to be quite limited and included flasks, small containers and drinking vessels. Moreover, there appear to have been quite a limited range of fabrics: the majority were covered with dark weathering, and the remainder are described as having green fabrics, although the selection of published colour photographs also include one sherd with a yellowish olive green fabric (Sasaki & Sasaki 1998: 111). Some were found broken *in situ* on plastered house floors, as in the case of Rooms 1 and 3 of House 3 in Area D, where the glassware finds included a juglet with an elongated pouring spout and low pushed-up base, a small jar and the top of a narrow-necked flask (Sasaki & Sasaki 1998: 108–110, pls 76–78, 80 = total wgt 1312.3 g). Fragmentary flasks, small bottles and the foot of a stemmed goblet covered with a dark weathering layer were found during the sieved excavation of the so-called "flat area 1" in Area D (Sasaki & Sasaki 1998: 112, pls 85–86); the excavation of Mound 3 in the same area of the site yielded four more sherds, including the body of a flask decorated with zigzag coiled trails applied between horizontal threads (Sasaki & Sasaki 1998: 114, pl. 93). These forms and fabrics compare very closely with the glass from Sir Bani Yas although their compositions have not been analysed.

The second assemblage to compare closely with Sir Bani Yas comes from graves excavated within a small cemetery on the eastern part of Kharg island which was probably originally associated with a nearby but since destroyed coastal village (Steve *et al*. 2003: 79–83, pls 44–50). A total of 62 graves were excavated, although some had been looted previously and the original above-ground appearance of the graves is uncertain. 18 graves were undisturbed and belonged to adults of both genders and children: ten of these contained a single glass vessel, and one contained as many as eight. The types included bottles with sloped down shoulders, rounded flasks decorated with zigzag coiled trails and a double-tube unguentarium supported on a camelid but the commonest forms were squat rounded bottles with short cylindrical or lightly flaring necks. The parallels cited (Steve *et al.* op. cit.) from Qasr-i Abu Nasr, Susa, al-Habibiyeh, Seleucia, Samarra and al-Rabadhah confirm a date between the second half of the eighth and the first part of the ninth century. The dating raises interesting questions over the religious beliefs of the deceased: they are far removed from the Christian monastery on the opposite side of the island and belong to a different community. The report suggests they may have been Jewish but the evidence is unconvincing and the more important point is that the cemetery proves that there was a variety of religious observances and local traditions for at least a century or more after the Islamic conquest.

Turning to other sites in the Persian Gulf and southern Iraq where churches and/or monasteries have been excavated, the comparative evidence is very thin. A small glass assemblage is published from the French excavations of a contemporary church on Akkaz island in the Bay of Kuwait (Nenna 2011). A total of 17 diagnostic glassware fragments were recovered during these investigations, of which five were from contexts associated with the church, four were from earlier periods and eight were unstratified; presumably a larger number of plain body fragments were found but not retained. Those pieces associated with the church consisted of two deep bowls or cylindrical beakers with infolded rims (Nenna 2011: 291–92, fig. 2, nos 4–5), a small jar which was catalogued as a tulip-shaped beaker (Nenna 2011: 292, fig. 2, no. 7), the concave base of a vessel, possibly another beaker (Nenna 2011: 292, fig. 2, no. 8), and a shallow bowl (Nenna 2011: 292, fig. 2, no. 11). The fabrics are not described but the last three were covered with thick beige, cream or cream and black weathering layers. The closest parallels cited were for the cylindrical beakers with infolded rims, namely Tell Baruda (Negro Ponzi 1987: fig. A, types B/D) and Uruk (Van Ess & Pedde 1992: 167, nos 1233, 1235).

Compositional Analysis of the Glass

The production of glass during the 1st millennium CE is divided into production using natron as a flux centred around the eastern Mediterranean and which appears to have ceased in the ninth century (Phelps et al. 2016), and that which involved the use of plant ash flux, which was the traditional technology of Mesopotamia. A growing body of data is allowing the characterisation of plant ash glass of this region. In more recent work the plant ash glass of Mesopotamia and Iran have been grouped into two major compositional types designated Mesopotamian Type 1 and Mesopotamian Type 2 (Phelps 2016; Phelps 2018).

Analytical Method

Small samples were removed from eighty-five fragments of glass from Sir Bani Yas, mounted in epoxy resin and polished down to 1 µm. The samples were vacuum coated with a thin layer of carbon and analysed in a JEOL JXA 8100 microprobe with three wavelength dispersive spectrometers, operated at 15 kV accelerating potential, beam current 50 nA, working distance of 10 mm and rastered at a magnification of x800. X-rays were collected for 30s on peak and 10s on each background. Standards were pure elements, oxides and minerals of known composition. Seven areas were analysed on each sample and the mean taken. Corning Museum Ancient Glass Standards A and B were measured eleven times each during the same analytical run, and the measurements compare well with the given values with components in excess of one percent absolute measured to within 8% relative of the given value.

Results

All 85 samples selected for analysis are soda-lime-silica glass with high (>1.5%) magnesia and potash contents, consistent with the use of plant ash as the flux (e.g. Liliquist et al 1993).

The compositional data were explored using hierarchical cluster analysis (HCA; Ward's Method), principal component analysis (PCA) and graphical methods. These identified four primary groups using eight components (MgO, Al_2O_3, SiO_2, P_2O_5, K_2O, CaO, TiO_2, Fe_2O_3) which incorporate contributions from both the plant ash flux and the silica source, and so account for differences in both recipe and raw materials. Soda, which did not vary greatly between the samples, was not used. The HCA results are shown in the dendrogram, Fig. 2, where the largest of the four groups, Group 1, is seen to separate at dissimilarity 600. The remaining groups fall to the right-hand side of the diagram. Group 3 separates at dissimilarity 200, while Group 2 and 4 divide at around dissimilarity 90. Some minor subdivisions are also apparent and are discussed below. Further minor adjustments to the groups were made based on specific elements: 1420c, 1201e and 1246b were reallocated due to their relatively high lime and low magnesia making these samples more similar in flux to those from Group 1; 1299, 1258a and G7a were relocated due to the higher alumina and phosphorous oxide of the first two samples and the MgO/CaO ratio of the latter sample, making them more characteristic of Group 2. The elemental weightings for the vessels within the groups are displayed in the PCA in Figure 3 with the reallocated samples also marked. This diagram displays principle components 1 and 2, accounting for 81.34% of the total variation. Mean compositions and standard deviations of the groups are reported in Table 4. Individual sample results are presented in Appendix B.

Fig. 2 near here

Fig. 3 near here

Table 4 near here

Group 1

Group 1 contains 51 vessels. These are mainly light blue-green bottles, jars, bowls and jugs, with a single sample recorded as colourless (1417d). This group is especially distinguished by its high levels of CaO (m=10.14%; 8 – 12%) and P_2O_5 (m=0.35%), which are the highest of all the glass analysed (Table 4). Low MgO/CaO (0.4) and K_2O/P_2O_5 (6.5) (Figure 5) emphasise that the distinguishing features are likely to relate to the plant ash. However, components relating to the silica source, such as Al_2O_3, Fe_2O_3 and TiO_2 are also high relative to the other groups (Table 6; Figures 7 and 8).

In Figure 2 a sub-set of 9 samples can be seen to branch at around dissimilarity 90. These vessels have a higher average Al_2O_3, Fe_2O_3 and TiO_2 (5.0%; 1.9%; 0.3%; Figure 8) but with similar flux contents to the rest of Group 1. This may represent natural variation in a single sand source, but could also represent a separate production location using new sand with a similar plant ash.

Another variation within this group is in the use of manganese oxide. This compound can be utilised as a decolourant, acting to oxidise the strongly coloured Fe^{2+} to the weakly coloured Fe^{3+} (Sayre 1963, Schreurs and Brill 1984, Mirti et al 2002). Previous work has suggested the natural levels of MnO in plant ash glass is around 0.2%, substantially higher that the 0.02% in natron-based glass (Phelps 2016). Almost 40% of the vessels of Group 1 had concentrations above 0.2%, up to a maximum of 1.72% and typically around 1%. The use of MnO might indicate chronological variation as it was not a common additive in Sasanian glass making, but is ubiquitous in 9th century Islamic glass, as discussed below.

Fig. 5 near here

Table 6 near here

Fig. 7 near here

Fig. 8 near here

Group 2

This is the second largest group containing 19 samples. Identified forms include bowls, one of which has facet cut decoration, and the most frequent vessel colour is light green. Although similar to Group 1 in general terms, this group is distinctive in its higher MgO/CaO and K_2O/P_2O_5 ratios (Fig. 5), arising from its lower lime (8.3%), higher magnesia (4.9%) and higher potash (2.8%). With respect to the silica source, Group 2 has Fe_2O_3, Al_2O_3 and TiO_2 lower than Group 1 but higher than the other groups recognised (Fig. 8). No further sub-divisions were recognisable within Group 2, although five samples contained elevated MnO, up to almost 1%.

Group 3

This is a small group of 9 samples, three of which (1480f; 1480h; 1480e) are identical within experimental error and are from the same batch and may represent the same vessel. The most frequent colours are colourless, grey or light grey and, given the masking effect of the weathered layers, suggest that this glass was primarily a clear colourless.

Group 3 is compositionally very distinctive; the average flux ratios (Table 6) are very high, pulling the samples towards the upper right of Figure 5. High levels of magnesia and low phosphorus oxide indicate the use of a different flux. Al_2O_3, Fe_2O_3 and TiO_2 are also the lowest of the groups, suggesting a silica source low in impurities (Table 6, Fig. 8).

Four vessels from Group 3 have MnO above 0.2%, the highest proportion of all of the identified groups (this proportion increases if the 3 identical samples are treated as a single vessel). The individual MnO contents are generally low however, ranging 0.3-0.4%, possibly because the purity of the silica source may have meant that only small quantities of MnO were required to produce the desired decolourising effect. MnO at similar levels is seen in the Nishapur Colourless glass group (Brill 1995), which Group 3 resembles (see below).

Group 4

Group 4 contains 6 samples (two of which may be from the same vessel). One identified form was a juglet with a trailed handle, and the most frequent colour was light green. While Group 4 lies on the same branch of the dendrogram as Group 2 in Figure 2, it is nonetheless distinct. The flux element ratios are low (MgO/CaO = 0.4 and K_2O/P_2O_5 =10.2), with notably high lime (9.3%) and low MgO (3.9%; Fig. 5). Silica source elements (Al_2O_3, Fe_2O_3 and TiO_2; Fig. 8) are low in abundance, again demonstrating the use of sand with low levels of impurities. Two samples (one vessel?) had added MnO at 1.4%, while in the other samples it was at background levels.

Discussion

Of major interest is what the glass can say about how Sir Bani Yas connected to the wider region and the dating of this site. Trade links to Mesopotamia were important during the Sasanian period and this continued after the Islamic conquest. Excavated ceramics from the church and monastery complex at al-Khor give direct evidence for this trade. Finds include late Parthian-Sasanian styled pottery typical to the Early Islamic transitional period (King et al 1995, 71), and among these are well known pottery types from Iraq, such as light buff wares rich in sand, as well as other buff wares more related to fine Abbasid light wares from Mesopotamia and Iran. The pottery indicates Mesopotamian imports dating to the Early Islamic period. During the ninth century this trade strengthened, centred around Baghdad, with Basra forming the principal trading port of the Persian Gulf. This declined in the tenth century as trade shifted to the Red Sea and Fatimid Cairo. Trade with India is also attested in pre-Islamic times, with documentary evidence of merchants from Sind, India and China at the nearby major port of Dibba, on the east coast of the UAE (King 2001, 80). The finding of India pottery at the fortress of Kush, dating to the sixth-seventh century (ibid, 75), further attests to this trade, although the ceramics from Sir Bani Yas do not provide evidence for an Indian link.

Available comparative compositional data

Production centres of plant ash glass dating to the Islamic period have been identified at Raqqa, Syria (late eighth-twelfth century; Henderson 1999; Henderson et al 2004) and Tyre, Lebanon (tenth-eleventh century; Aldsworth et al 2002). In addition, glass vessels have been analysed from the Sasanian period (Brill 1999; Mirti et al 2008; 2009) as well as from Islamic contexts (Brill 1995; 1999; Henderson et al 2016). Production sites in Iraq and Iran are recognised (Simpson 2014), however none have been studied in detail, although a number of compositional groups based on vessel glass from consumer sites have been characterised.

Analyses of glass from the region of Sir Bani Yas are scarce and no evidence for glass production is known from the Arabian Peninsula. Comparative data from the region comprises 18 samples of Sasanian-Early Islamic glass from the fortress at Kush (Freestone forthcoming) on the north coast of the UAE, and 9 samples of ninth-tenth century glass from the port of Siraf (Brill 1999), located on the Iranian coast (Fig. 1). In addition to these comparisons may be made with fourth-seventh century Sasanian and eighth-twelfth century Early Islamic glass from Mesopotamia and Iran, and to Islamic period glass from Israel, Syria, Lebanon and Egypt.

Phelps (2018; see also Phelps 2016) grouped plant ash glass from these regions into three broad groups: Eastern Mediterranean; Mesopotamian Type 1 and Mesopotamian Type 2. These groups are based mainly on differences in the components related to the plant ash, but also take into account the alumina content of the sand. It follows the observation of Freestone (2006) who noted flux-related differences between glass from the Eastern Mediterranean and that from Mesopotamia, possibly relating to the magnesia-rich sediments of the Tigris-Euphrates flood plain. The groups and literature data on which they are based are shown in Figure 9. These groupings incorporate a number of site-specific groups identified by previous authors. The average compositions of the literature groups and their relationship to the over-arching groupings used in the present paper are provided in Table 6.

Fig. 9 near here

The Eastern Mediterranean group (Fig. 9, Table 6) is characterised by glass with a low MgO content (3-4%) and very high CaO content (9-12%), and includes the tenth-eleventh century production site at Tyre, Lebanon (Freestone 2002), late eighth-twelfth century production site at Raqqa (Raqqa Type 1; Henderson 1999; Henderson et al 2004), eleventh-thirteenth century secondary production site at Banias, Israel (Freestone et al 2000), and tenth-twelfth century coin weights from Fustat, Egypt (Group 3 of Gratuze and Barrandon 1990).

Mesopotamian Type 1 and Mesopotamian Type 2 contain lower lime (5-7%) than eastern Mediterranean glass, however Mesopotamian Type 1 is generally higher in magnesia and potash and tends towards higher alumina. The glass of this type includes the groups Sasanian 1 (Mirti et al 2008, 2009), Samarra Type B (Wypyski 2015) and the Nishapur Coloured glass of Brill (1995). Mesopotamian Type 2 is distinguished by even higher magnesia (4-8%), giving a high MgO/CaO ratio, and has particularly low levels of phosphate for plant ash glass, typically less than 0.15% P_2O_5. Furthermore, Type 2 has low quantities of alumina, titania and iron (Table 6), indicative of the use of a relatively pure sand or possibly quartz pebbles as a source of silica. Previously identified glass groups incorporated in Type 2 are Sasanian 2, Samarra Type A (including also the Samarra glass analysed by Henderson et al 2016), and Nishapur Coloured.

Affiliations of Sir Bani Yas Groups

Natron glass was not detected at Sir Bani Yas, indicating that this was not traded in any quantity from the eastern Mediterranean. Figure 10 compares the glass from Sir Bani Yas with the regional compositional groupings (Fig. 9) and additionally the analysed material from Kush and Siraf. It can be seen that SBY Groups 1 and 2, along with the majority of the glass from Kush, fall into the Mesopotamian Type 1 field, and SBY Group 3 in the Mesopotamian Type 2 field, along with scattered samples from Kush. Only vessels of SBY Group 4, the glass from Siraf, and 3 samples from Kush have the lower MgO/CaO and alumina contents suggestive of eastern Mediterranean traditions.

Fig. 10 near here

Figure 11 provides further discrimination; SBY Groups 2 and 3 still fall in the regions of Mesopotamian Types 1 and 2 respectively, both sharing similar low levels of lime, but differing in their titania contents. However, SBY Group 1 is much higher in lime and titania, indicating it is clearly different from the Mesopotamian types so far analysed. Furthermore, the alumina levels of SBY 1 are higher than is typical for Mesopotamian glass, although some overlap is seen with samples from Nishapur (Tables 4 and 6).

Fig. 11 near here

These results suggest that the vessels from SBY Groups 2 and 3 have compositions within the range of those being produced in Mesopotamia during Sasanian to early Islamic times. SBY Group 2 is similar to Mesopotamian Type 1 which, on the basis of its distribution, appears common to central Mesopotamia. Of this Type, SBY Group 2 is most similar to the Sasanian 1 of Mirti et al (2008; 2009). Ganio et al. (2013) conducted Sr and Nd isotopic investigations of Sasanian 1 glass and suggested production at more than one location within a similar geological region (Ganio et al 2013). On the other hand, SBY Group 3 is more similar to Mesopotamian Type 2. The Nishapur Colourless, Samarra Type A and the Sassanian 2 groups which comprise Mesopotamian Type 2 (Fig. 9) tended to be colourless in the Islamic period and had a higher percentage of vessels with cut decoration (Brill 1995; Wypyski 2015; Phelps 2018), suggesting this glass type to be associated with higher status vessels. SBY Group 3 also has a higher number of colourless vessels as well as increased use of MnO as a decolourant.

Overall, these similarities suggest that the vessels of Sir Bani Yas Groups 2 and 3 originated in Mesopotamia, consistent with the ceramic evidence at al-Khor which indicates the import of Early Islamic wares from Iraq. The vessels from Kush are also indicative of a predominantly Mesopotamian origin, with samples split over both the Mesopotamian Type 1 and 2 compositional groups.

Sir Bani Yas Group 1 is a previously unrecognised compositional type. It does not match glass from Mesopotamia, nor does it match vessels from Kush or Siraf. This group is the most abundant, potentially suggesting that this glass was more easily accessible, and thus it could represent a type made more locally. However, this glass could also have been imported. Wypyski (2015), in his investigation of glass from Nishapur, identifies a high alumina type he suggests came from Pakistan, although Group 1 is not an exact match due to differences in potash. On the other hand, we have few comparative analyses from Iranian sites so an origin in Iran is also possible. It should also be borne in mind that this glass might have been made in Mesopotamia and represent glass from an area where the magnesia-rich sediments of the flood plain are less dominant.

Finally, SBY Group 4, glass falls into the eastern Mediterranean region of Figure 10 alongside glass from Siraf and three samples from Kush. The similarities are less apparent in Figure 11, due to lower lime in the glass from Siraf, although the alumina and titania contents for all these samples remain similar. Alumina, titania and lime in Group 4 are also similar to production from Tyre and Raqqa. However, it seems unlikely that most of the glass from Siraf was imported from the Levant or Syria during this period and so these similarities in major element composition are probably misleading. It must be assumed that a source of glass beyond the eastern Mediterranean and Mesopotamia produced glass similar in composition to that produced in Egypt and the Levant. Given the overlap with Siraf, Iran would appear to be a likely source of SBY Group 4, but more data for glass from Iran would be required to demonstrate this. It seems possible that the vessels from Group 4, Siraf and 3 fragments from Kush form glass types local to the Gulf region, each using similar sands, but plants varying in their lime and magnesia contents.

Dating

25-44% of the vessels in the glass groups from Sir Bani Yas contained MnO above 0.2%. which is taken here to indicative deliberate addition. The addition of MnO is rare in Sasanian glass from Veh Ardašīr (Mirti et al 2008; 2009) however, in the Islamic period from around the late eighth century MnO use becomes almost universal, for example in glass from Raqqa (Type 1), Tyre, Samarra and in the Nishapur Colourless glass (although only 50% of the Nishapur Coloured group contains added MnO; Brill 1995). In Kush, only around 50% of the Sasanian-Islamic glass contained added MnO, while in ninth-tenth century Siraf all the samples had added MnO, ranging from 2.5-3.5%. This pattern of increased MnO usage in later centuries suggests the Sir Bani Yas glass to be relatively early and supports the seventh-eighth century dating currently proposed.

Conclusions

The glass recovered from the church and other buildings at Sir Bani Yas appears to be a typologically coherent assemblage. In form all of the glass appears to be attributable to the early Islamic period and there are no diagnostic Sasanian fragments. Furthermore, the range of findspots is similar to the pottery, indicating that the pottery and glass were part of the same single-period assemblage. The dating of these finds are consistent with occupation during the latter part of the seventh and/or eighth centuries and the closest parallels of the glassware include assemblages at Jazirat al-Hulayla and Kharg island.

The analysis of 85 samples identified soda-lime-silica glass made using plant ash flux. The use of MnO in a some of the glass is suggestive of the early Islamic period and in agreement with the seventh-eight century dating suggested by the pottery.

The glasses were categorised into four compositional groups based on differences in flux and silica source. The most common type (Group 1), was made with a plant ash high in lime but with relatively low magnesia, and a sand high in impurities. This does not compare well to previously analysed glass and its origin is unclear. Groups 2 and 3 demonstrate close similarities to Mesopotamian glass types. This suggests a possible trade in these vessels from Iraq, and although this should be confirmed by trace elemental or isotopic data, it is consistent with the finding of early Islamic pottery from Iraq on the site. Group 4 is a small group, from an unknown source, possibly in the Gulf region, perhaps near the coast of Iran. Unpublished data for vessels from Kush similarly fall into these compositional groups. There was no natron glass, nor any plant ash glass matching known Syrian compositions. It therefore appears that this site was not trading significant numbers of vessels with the eastern Mediterranean at this time.

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Figures

Figure 1. Map of the region. The island of Sir Bani Yas is shown alongside sites mentioned in the text marked in red.

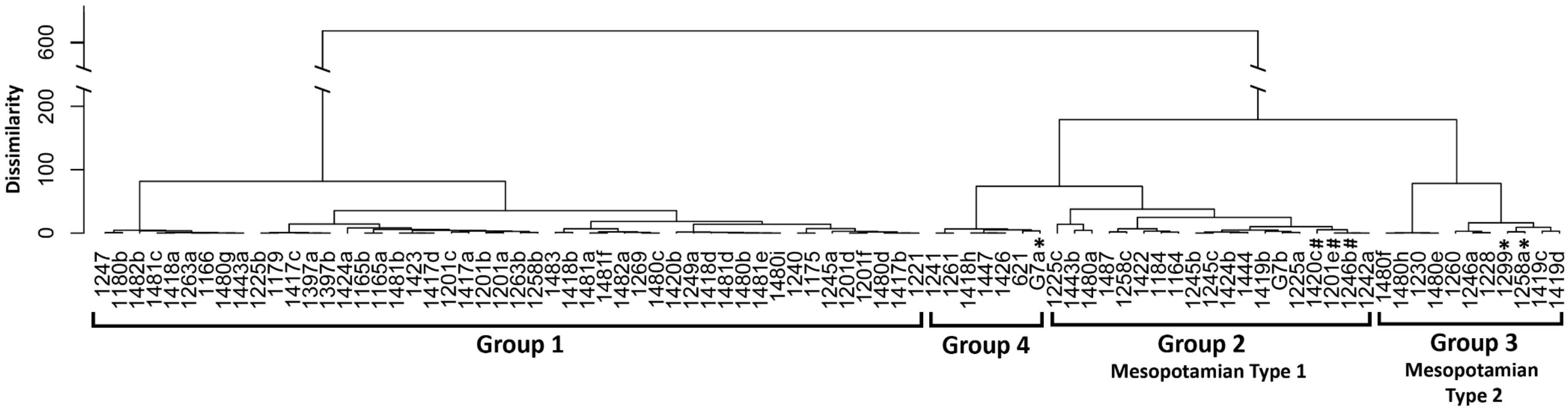

*Figure 2. Dendrogram displaying the results of hierarchical cluster analysis using Ward's Method. The four principal groups as identified in the text are labelled. N = 85. Elements: MgO, Al_2O_3, SiO_2, P_2O_5, K_2O, CaO, TiO_2, Fe_2O_3. Six samples have been manually reassigned (see text for details): # = samples moved to Group 1; * = samples moved to Group 2.*

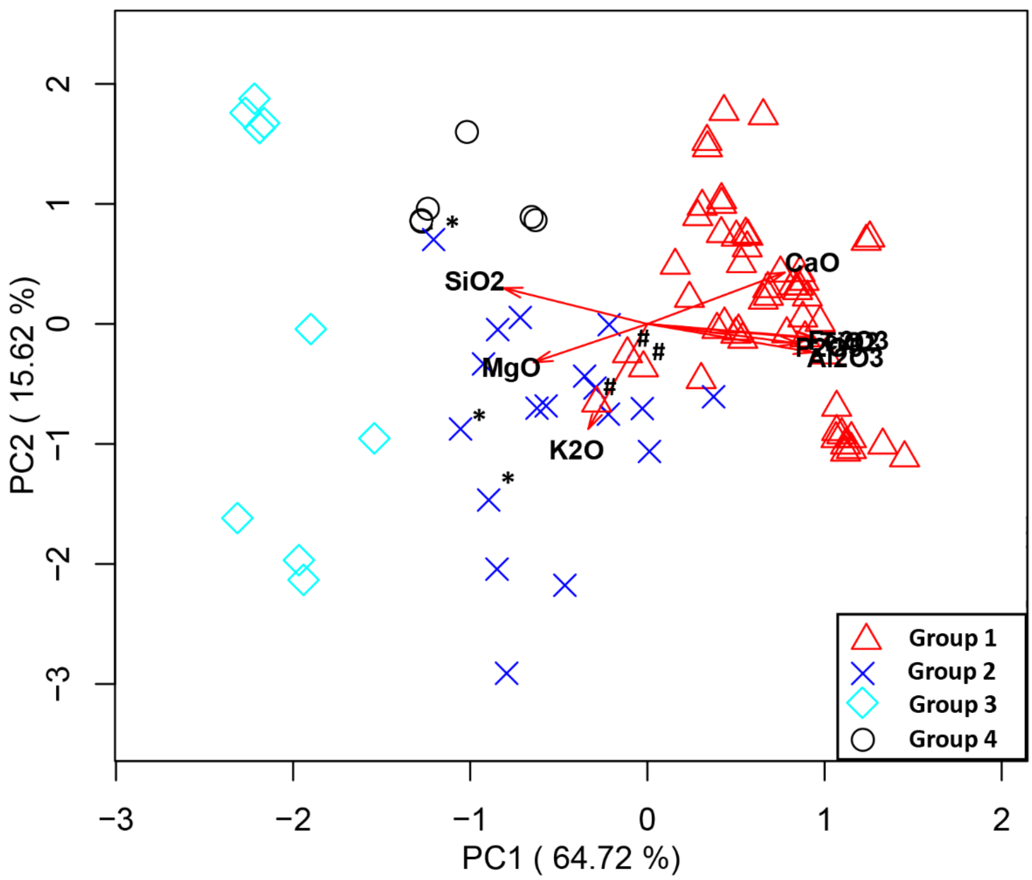

*Figure 3. Bivariate plot displaying principal components 1 and 2. Groups and elements as indicated in Figure 1. # = samples re-allocated to Group 1; * = samples re-allocated to Group 2.*

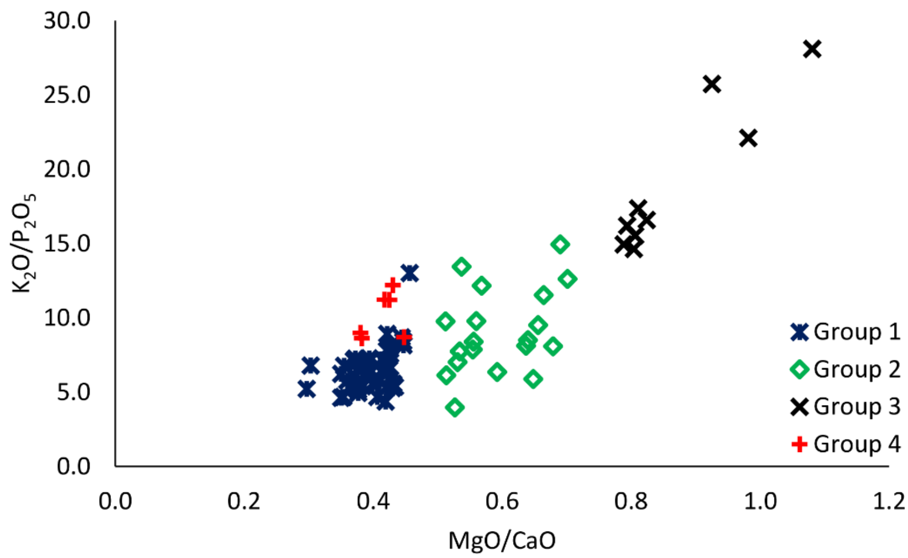

Figure 5. Diagram comparing the ratios of flux-related components in the four identified groups. Separation indicates the use of different plant ashes.

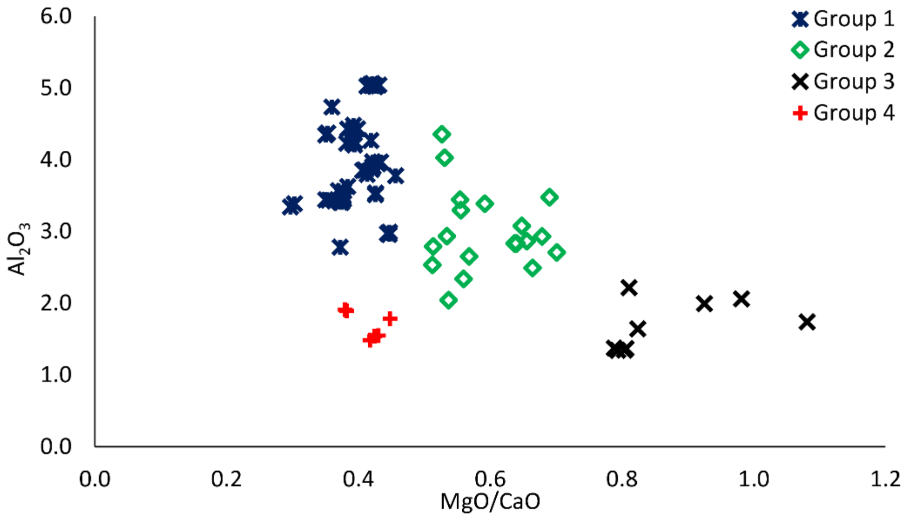

Figure 7. Alumina vs MgO/CaO for the four main glass groups from Sir Bani Yas. Wt %.

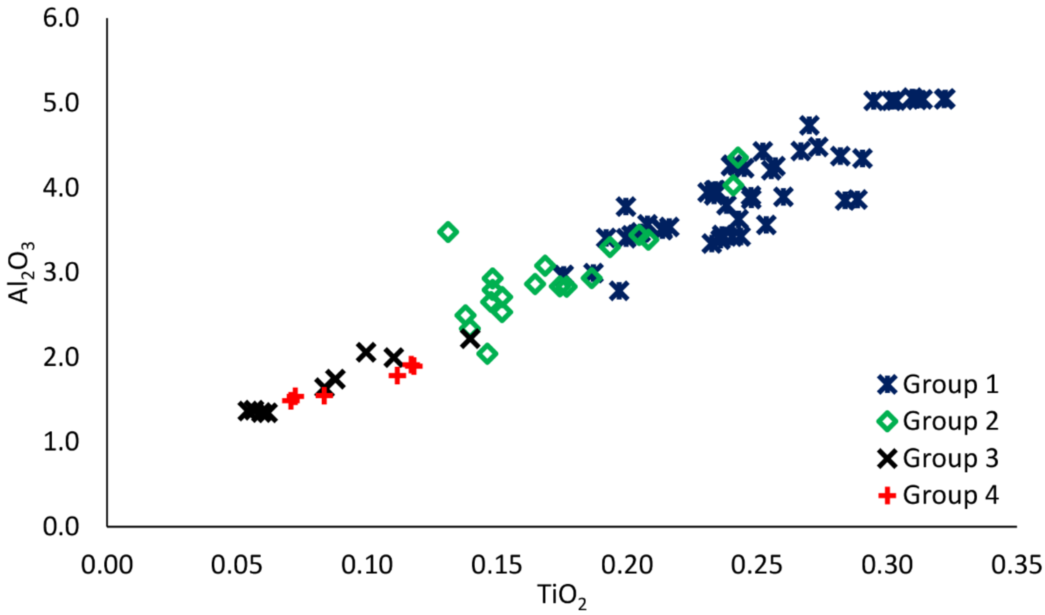

Figure 8. Alumina vs titania for the four main glass groups *from Sir Bani Yas*. Wt %.

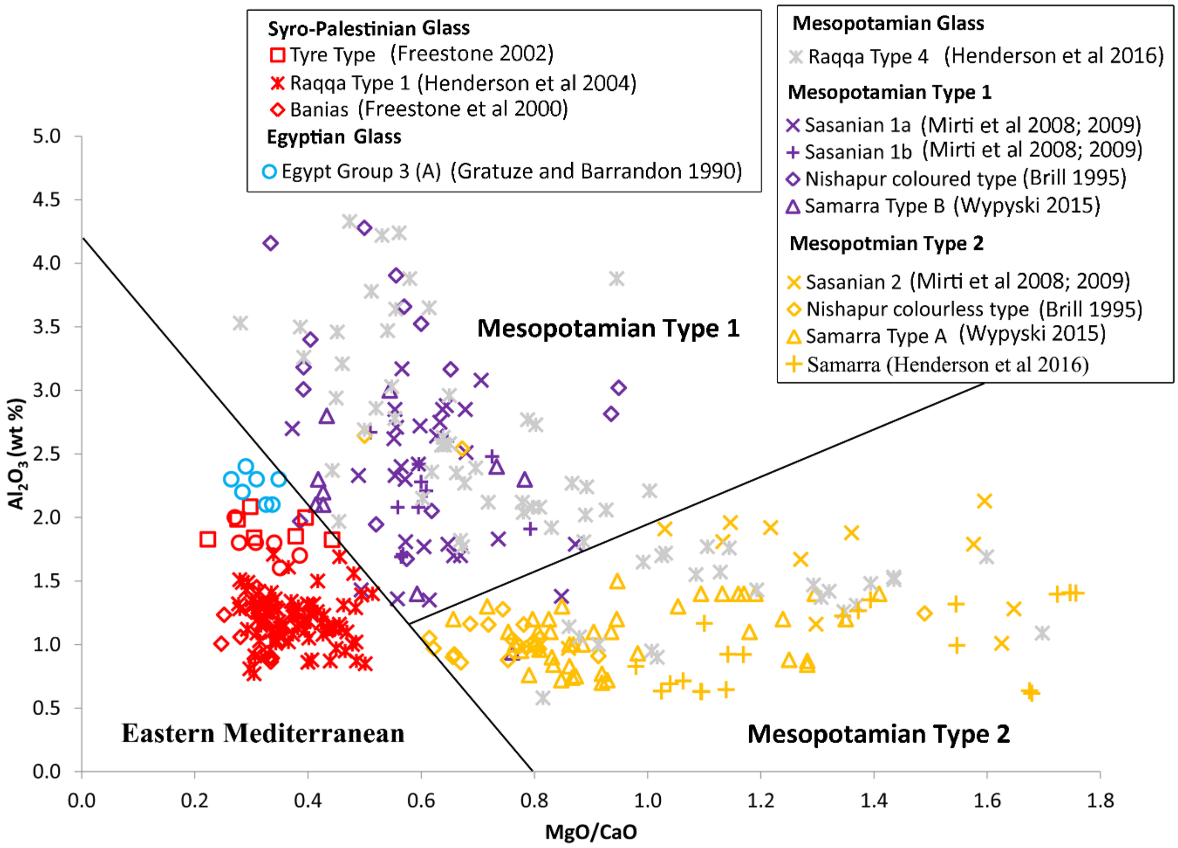

Figure 9. Major groups of Near and Middle Eastern plant ash glass according to Phelps (2016, 2018) dating to the Sasanian (Veh Ardašīr; 3rd-7th) and Early Islamic (remaining sites; late 8th-11th) periods (data sources in key). The samples are coloured to highlight group similarities.

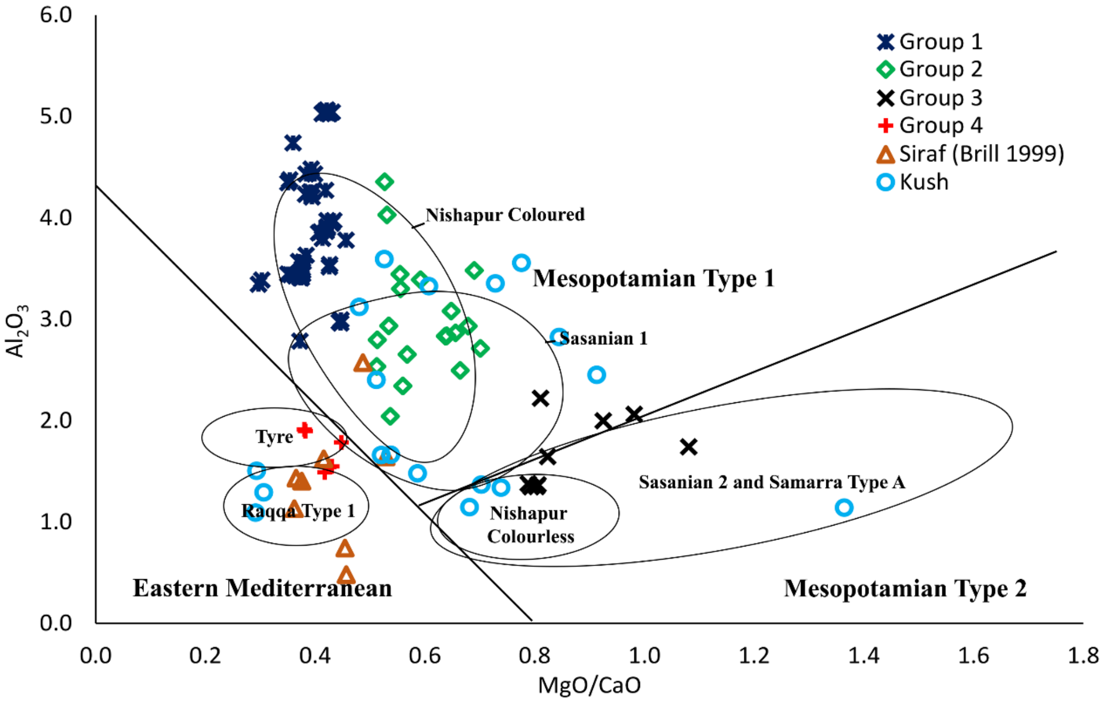

Figure 10. The four glass groups identified from Sir Bani Yas displayed alongside glass from 9th-10th century Siraf (Brill 1999) and Sasanian-Islamic glass from Kush (Freestone forthcoming). Labelled ellipses represent the site-specific groupings previously recognised in the literature; major linear boundaries are from Fig. 9.

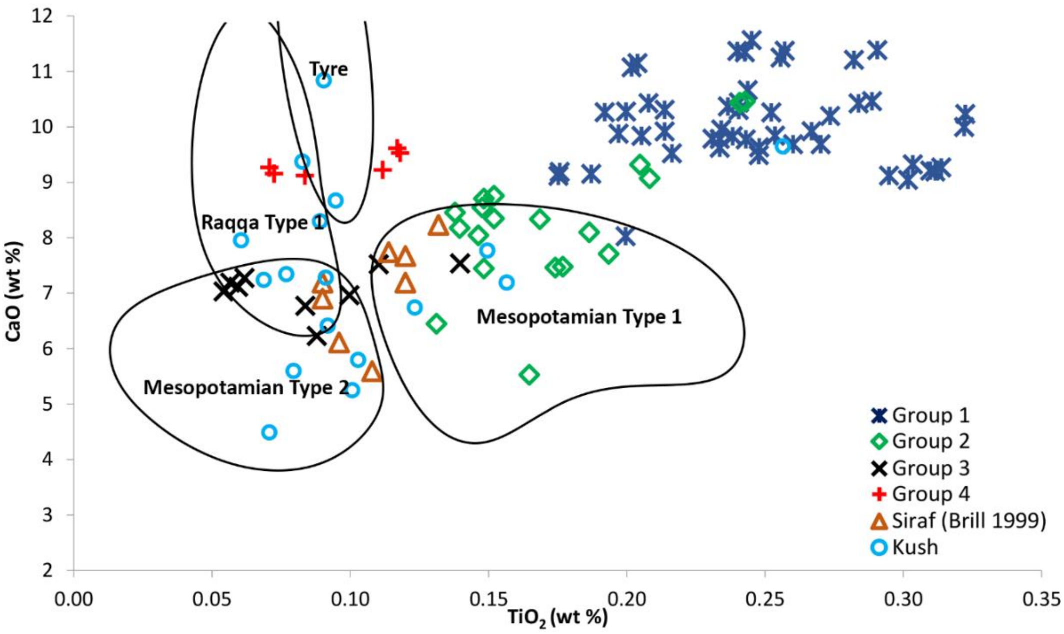

Figure 11. Bivariate plot of CaO vs. TiO_2 demonstrating the separation of Group 1 from the other glass types. Groups 2 and 3 conform to Mesopotamian Type 1 and Type 2 respectively.

Tables

Figure 4. Average group composition of glass from Sir Bani Yas. Selected major and minor elements. Wt %. ***N*** *= number of samples;* ***m*** *= mean; sd = standard deviation.*

	N		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	SrO	MgO/CaO	K_2O/P_2O_5
Group 1	51	**m**	**15.04**	**4.01**	**3.97**	**60.38**	**0.36**	**0.65**	**2.28**	**10.14**	**0.25**	**0.39**	**1.47**	**0.10**	**0.40**	**6.50**
		sd	*0.71*	*0.25*	*0.63*	*1.06*	*0.06*	*0.15*	*0.33*	*0.85*	*0.04*	*0.49*	*0.25*	*0.02*	*0.03*	*1.44*
Group 2	19	***m***	***15.81***	***4.87***	***3.00***	***61.48***	***0.33***	***0.82***	***2.82***	***8.25***	***0.17***	***0.26***	**1.00**	***0.11***	***0.59***	***9.05***
		sd	*0.77*	*0.62*	*0.56*	*1.76*	*0.07*	*0.19*	*0.55*	*1.18*	*0.03*	*0.31*	*0.20*	*0.02*	*0.07*	*2.84*
Group 3	9	**m**	**14.99**	**6.12**	**1.68**	**64.67**	**0.13**	**0.87**	**2.59**	**7.07**	**0.08**	**0.19**	**0.47**	**0.12**	**0.87**	**19.02**
		sd	*0.66*	*0.57*	*0.35*	*2.08*	*0.02*	*0.16*	*0.86*	*0.40*	*0.03*	*0.19*	*0.08*	*0.02*	*0.10*	*5.02*
Group 4	6	***m***	***15.11***	***3.85***	***1.70***	***63.94***	***0.25***	***0.71***	**2.55**	***9.32***	***0.10***	***0.51***	**0.78**	***0.13***	***0.41***	***10.16***
		sd	*0.49*	*0.18*	*0.19*	*1.28*	*0.03*	*0.26*	*0.23*	*0.21*	*0.02*	*0.69*	*0.14*	*0.02*	*0.03*	*1.56*

Figure 6. Average values for selected major and minor elements for a range of comparative data. Group distinctions the same as those reported in Figure 8. Wt %. ***N** = number of samples; **m** = mean; sd = standard deviation. Data sources at base of table.*

Location	Type	Date	N		Na_2O	MgO	Al_2O_3	SiO2	P_2O_5	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	MgO/CaO	K_2O/P_2O_5
Siraf, Iran[§]		9th-10th	8	**m**	**12.04**	**3.03**	**1.38**	**70.16**	**n/a**	**n/a**	**2.98**	**7.08**	**0.11**	**1.92**	**0.95**	**0.43**	**n/a**
				sd	*0.86*	*0.43*	*0.64*	*1.77*	*n/a*	*n/a*	*0.61*	*0.87*	*0.02*	*1.07*	*0.27*	*0.06*	*n/a*
Eastern Mediterranean																	
Tyre, Lebanon*	Tyre Type	10th-11th	8	**m**	**12.85**	**3.61**	**1.81**	**65.06**	**0.33**	**0.76**	**2.26**	**11.21**	**0.09**	**1.33**	**0.54**	0.32	6.85
				sd	*1.22*	*0.26*	*0.32*	*1.65*	*0.05*	*0.11*	*0.22*	*2.15*	*0.01*	*0.67*	*0.05*		
Raqqa, Syria[‡]	Raqqa Type 1	8th-11th	90	**m**	**12.93**	**3.43**	**1.2**	**67.49**	**0.28**	**0.77**	**2.52**	**9.31**	**0.07**	**1.14**	**0.56**	0.37	9.00
				sd	*1.4*	*0.32*	*0.19*	*1.51*	*0.04*	*0.13*	*0.36*	*1.45*	*0.01*	*0.55*	*0.31*		
Mesopotamian Type 1																	
Veh Ardašīr, Iraq[#]	Sasanian 1a	3th-7th	29	**m**	**16.01**	**4.05**	**2.28**	**60.02**	**0.31**	**n/a**	**3.32**	**6.7**	**0.18**	**0.15**	**1.09**	0.60	10.71
				sd	*1.39*	*0.43*	*0.57*	*2.52*	*0.06*	*n/a*	*0.42*	*1.03*	*0.04*	*0.42*	*0.32*		
	Sasanian 1b	3th-7th	11	**m**	**16.02**	**4.1**	**2.19**	**60.49**	**0.27**	**n/a**	**3.41**	**6.74**	**0.13**	**0.12**	**0.91**	0.61	12.63
				sd	*1.44*	*0.43*	*0.34*	*1.76*	*0.07*	*n/a*	*0.4*	*0.83*	*0.03*	*0.25*	*0.21*		
Nishapur, Iran†	Nishapur Coloured	9th-10th	15	**m**	**15.86**	**3.76**	**3.05**	**64.68**	**0.32**	**0.76**	**2.91**	**6.78**	**0.15**	**0.39**	**1.12**	0.55	9.09
				sd	*1.63*	*1.22*	*0.83*	*2.63*	*0.08*	*0.19*	*0.5*	*1.03*	*0.04*	*0.45*	*0.2*		
Mesopotamian Type 2																	
Veh Ardašīr, Iraq[#]	Sasanian 2	3th-7th	13	**m**	**17.43**	**7.13**	**1.62**	**58.63**	**0.13**	**n/a**	**2.8**	**5.55**	**0.09**	**0.18**	**0.6**	1.28	21.54
				sd	*1.14*	*0.93*	*0.41*	*3.16*	*0.02*	*n/a*	*0.42*	*0.88*	*0.02*	*0.21*	*0.17*		
Nishapur, Iran†	Nishapur Colourless	9th-10th	22	**m**	**12.53**	**4.69**	**1.17**	**71.18**	**0.12**	**0.65**	**2.45**	**6.27**	**0.05**	**0.4**	**0.37**	0.75	20.42
				sd	*1.48*	*0.57*	*0.48*	*2.52*	*0.06*	*0.08*	*0.38*	*0.67*	*0.03*	*0.2*	*0.23*		
Samarra, Iraq[#]		9th-10th	21	**m**	**14.50**	**6.66**	**0.94**	**67.9**	**0.08**	**n/a**	**2.45**	**5.09**	**0.06**	**0.85**	**0.4**	1.37	34.08
				sd	*1.29*	*0.83*	*0.33*	*2.43*	*0.03*	*n/a*	*0.41*	*1.15*	*0.02*	*0.87*	*0.21*		

§ = Data Brill (1999, 173). Cobalt blue sample not included.

*LA-ICP-MS re-analysed by Phelps and Freestone; Tyre - cobalt coloured and single very high lime sample omitted.

† = Samples of Brill (1995) re-analysed by Lankton (pers. comms.) using LA-ICP-MS. Self-coloured samples only.

= sol ICP-MS data from Mirti et al (2008; 2009). Samples selected Veh Ardašīr only.

‡ = Data Henderson et al (2004).

***Appendix A**: Context, metrics and descriptions of the glass vessels sorted by compositional group. Length (L), width (W) and thickness (T) in cm. Weight (Wgt) in grams.*

Inventory	Description	L	W	T	Wgt	Site	Ctx
Group 1	**Unknown Type**						
1483	possibly part of a base; light green with yellow weathering	1.6	1.2	0.5	1.15	SBY-9	1
1418b	base with push-up; 3 sherds (largest measured); possibly same vessel as 1418a	2.2	1.1	0.5	3.08	SBY-9	150
1165b	same vessel as 1165a?	3.0	2.5	0.1	1.55	SBY-9	1
1481a	flared cylinder with applied pad on the underside; dark with dark grey weathering	3.0	2.0	0.2	4.00	SBY-9	125
1165a	body; light green with yellow weathering	4.2	2.5	0.2	3.61	SBY-9	1
1481f	body; dark with dark grey weathering; 9 sherds (largest measured)	1.7	0.9	0.1	0.99	SBY-9	125
1480d	body; semi-transparent light green with partial white/yellow weathering; 3 sherds	2.8	2.1	0.2	2.23	SBY-9	125
1482a	body; light blue-green with no weathering	2.0	1.0	0.1	0.66	SBY-9	1
1269	base with indistinct possibly hollow pontil mark (BD ca 10, 12.5% preserved; push-up H 0.2); light green with yellow weathering	6.5	3.8	0.3 (0.8 base)	17.50	SBY-9	125
1417b	body; light green with milky weathering; 2 sherds	3.2 – 4.3	1.9 – 2.3	0.2	4.29	SBY-9	1
1245a	body; dark with dark grey weathering	4.3	2.0	0.2	1.55	SBY-7	5
1480c	base with shallow wide hollow pontil mark (D 2.5) on the underside (BD 8, 50% preserved); semi-transparent light blue-green with partial milky weathering	6.5	3.5	0.3 (wall) 0.6 (base)	21.50	SBY-9	125
1201d	lug; grey brown weathering	3.5	2.5	0.1	5.50	SBY-7	11
1201f	body; dark green with dark grey weathering; 6 sherds (largest measured); same vessel as 1201e	1.6	1.3	0.1	0.89	SBY-7	11
1221	body; light green with pale weathering	4.1	2.1	0.2	2.00	SBY-9	130
1240	body; light green with yellow weathering	5.9	2.4	0.3	4.50	SBY-7	12
1417c	body; light green with yellow weathering	2.9	2.0	0.2	1.08	SBY-9	1
1201c	small jar; body light green with yellow brown weathering	1.5	3.0	0.3	5.54	SBY-7	11
1175	body; light green with slightly yellow weathering	2.5	2.0	0.1	0.81	SBY-7	2
1397a	body; light green with white weathering on one side	1.8	1.5	0.3	1.23	SBY-4	1
1225b	body; semi-transparent light green with no weathering	2.1	1.2	0.2	0.62	SBY-9	114
1201b	infolded rim of straight-sided bowl (RD 8, 75% preserved); light green with yellow weathering; 3 sherds	4.5 (x3); 2	1.0	0.1 (wall), 0.3 (rim)	9.00	SBY-7	11
1397b	body; same vessel as 1397a	2.0	1.1	0.3	1.12	SBY-4	1

1179	body; semi-transparent light blue-green with no weathering	3.2	2.6	0.2	2.00	SBY-9	1
1201a	base (BD 7, 75% preserved, push-up H 0.5); no pontil mark; light green with yellow brown weathering	7.2	5.5	0.2	26.50	SBY-7	11
1263b	body; light green with yellow weathering	1.7	1.5	0.2	0.61	SBY-9	115
1258b	body; light green with yellow weathering	2.7	1.6	0.2	1.00	SBY-9	127
1481d	rim; straight-sided or cylindrical	1.7	2.0	0.2	1.02	SBY-9	125
1417a	rim of bottle with cylindrical neck (H 2.5, ext RD 2.9, int RD 0.7, 100% preserved, H neck 2); light green with opaque grey weathering	2.5	2.8	0.1 (wall)	10.50	SBY-9	1
1481e	body; 3 sherds; same vessel as 1481d (largest measured)	2.1	1.5	0.2	2.12	SBY-9	125
1480b	rim of straight-sided bowl (RD uncertain); dark with dark grey weathering	2.0	1.5	0.1	0.81	SBY-9	125
1418d	body; dark with dark grey weathering	2.3	1.9	0.2	1.50	SBY-9	150
1481b	narrow cylindrical neck and sloping shoulder; dark with dark grey weathering; 3 sherds	2.0	1.8	0.2	2.51	SBY-9	125
1480i	body and part of the neck; dark with dark grey weathering; 5 sherds (smallest and largest measured); probably the same vessel as 1480b	1.8–3.6	0.5 - 0.9	0.2	2.78	SBY-9	125
1420b	light grey with light grey weathering; 2 sherds; possibly same vessel as 1420a	2.5	0.8	0.2	1.05	SBY-9	170
1249a	part of stemmed goblet (stem D 1) with low moulding around the stem/bowl junction; dark with dull opaque grey weathering	2.3	3.7	0.2	8.75	SBY-9	130
1423	tubular spout (D 0.7); dark with even opaque grey weathering	3.0	0.7	0.1	1.00	SBY-9	233
1417d	body; almost transparent with light grey weathering	2.3	1.8	0.1	0.83	SBY-9	1
1242a	body; semi-transparent dark green with no weathering	4.1	2.5	0.3	4.07	SBY-7	1
1246b	body; dark with dark grey weathering	1.8	1.0	0.3	1.50	SBY-7	5
1201e	body; dark green with dark grey weathering; 17 sherds (largest and smallest measured); same vessel as 1201d	11.0	3.5	0.3	77.53	SBY-7	11
1420c	shoulder of small jar with rounded body; light green with milky weathering; 4 sherds	4.0	2.1	0.3	4.06	SBY-9	170
1482b	body; light green with yellow weathering	2.1	1.7	0.1	0.86	SBY-9	1
1480g	body; light green with dark yellow weathering	3.2	2.5	0.3	3.00	SBY-9	125
1481c	body; light green with yellow weathering and partial light brown weathering crust	3.0	1.4	0.3	1.50	SBY-9	125
1247	body; dark with dark grey weathering	5.8	1.9	0.2	3.50	SBY-7	5
1263a	body; light green with even light brown weathering	2.5	1.8	0.4	3.00	SBY-9	115
1418a	light grey with light grey weathering; 2 sherds; possibly same vessel as 1420a	3.7	2.0	0.3	4.75	SBY-9	150

1443a	body; light green with yellow-brown weathering	1.5	0.6	0.1	0.15	SBY-9	173
1166	possibly the neck of a tall bottle, with a light horizontal wheel-cut line on the exterior (H 4.8); semi-transparent dark green with no weathering	4.8	2.6	0.3-0.5	7.65	SBY-9	1
1180b	body; light green with yellow weathering	5.3	3.6	0.2	5.50	SBY-7	4
Group 2	**Mesopotamian Type 1**						
G7b	body; semi-transparent light green with partial milky weathering; 3 sherds (largest measured)	2.3	1.6	0.2	2.52	SBY-9	1
1487	base; light green with yellow weathering	1.7	1.6	0.4–0.7	2.00	SBY-9	196
1424a	body; semi-transparent light green with no weathering	1.5	1.2	0.1	0.34	SBY-9	201
1422	body; semi-transparent light green with patch of yellow-brown weathering	1.9	1.1	0.2	0.57	SBY-9	157
1424b	body; light green with milky weathering	1.6	1.0	0.2	0.30	SBY-9	201
G7a	rim of thin-walled straight-sided bowl (RD 10–12, ca 10% preserved, H 1.5); light grey with opaque light grey weathering	3.0	1.5	0.1	1.50	SBY-9	1
1184	base; push-up; light green with no weathering	1.7	1.5	0.3	0.75	SBY-9	128
1444	body; light green with yellow weathering	1.6	1.2	0.2	0.32	SBY-9	212
1225a	base with facet (D 1.2) removing any trace of a pontil mark; light green with yellow weathering	3.5	3.5	0.2 (wall) 0.5 (base)	5.24	SBY-9	114
1443b	body; grey-brown weathering	1.5	1.0	0.1	0.16	SBY-9	173
1164	body; light green with yellow weathering	2.5	1.4	0.2	1.00	SBY-9	1
1245b	body; devitrified with light brown weathering	2.0	0.7	0.2	0.15	SBY-7	5
1245c	body; devitrified with light brown weathering	1.1	1.0	0.1	0.10	SBY-7	5
1258c	body; light blue-green with no weathering; 2 sherds	2.1	2.0	0.1	1.00	SBY-9	127
1225c	body; almost transparent light blue-green with no weathering	1.6	1.0	0.1	0.23	SBY-9	114
1299	rim of thin-walled straight-sided bowl with lightly fire-thickened rim (RD 9; 12.5% preserved, H 3); opaque light grey weathering	4.0	3.0	0.1	2.50	SBY-2	9
1419b	base; light green with opaque white weathering; 3 sherds (largest measured)	1.8	1.0	0.3	0.85	SBY-9	131
1480a	rim of open bowl (RD 22, 15% preserved); grey-brown weathering; 2 joining sherds	9.5	2.7	0.1	9.50	SBY-9	125
1258a	infolded rim of straight-sided bowl (RD 10, 12.5% preserved); light green with milky yellow weathering	4.0	3.3	0.2	6.00	SBY-9	127

Group 3	**Mesopotamian Type 2**						
1419c	body; devitrified with white weathering; 2 sherds	1.8	0.9	0.1	0.50	SBY-9	131
1260	base (push-up H 0.5); possibly grey with opaque dark brown weathering	4.0	3.0	0.2 (wall)	6.83	SBY-9	115
1246a	base (push-up H 0.5); hollow circular pontil mark (int D 0.6); light grey (?) with light grey opaque weathering	4.2	3.5	0.2 (wall)	8.00	SBY-7	5
1228	base (push-up H 0.8) with hollow pontil (ext D 1.3); grey with opaque milky white weathering	5.8	4.6	0.1	15.50	SBY-9	123
1419d	body; dark with dark grey weathering; 3 sherds	1.2	0.8	0.1	0.15	SBY-9	131
1480f	rim of hemispherical bowl with fire-thickened rim (H 2.4, RD uncertain); almost clear with white weathering; probably same vessel as 1480e, h	2.4	1.5	0.2 (0.3 at rim)	1.05	SBY-9	125
1480h	body; almost clear with white weathering; probably same vessel as 1480e-f	2.9	2.0	0.2	1.50	SBY-9	125
1230	body; clear transparent (decolourised); dull weathered surfaces	1.0	2.3	0.3	1.21	SBY-9	1
1480e	body; almost clear with white weathering; probably same vessel as 1480f, h	3.5	1.7	0.2	2.01	SBY-9	125
Group 4	**Unknown (local?) Type**						
1447	juglet with fire-polished rim and short cylindrical neck, rounded body and pushed-up base with a single trailed handle attached to the shoulder and upper neck; pale blue-green with white weathering; 3 sherds	-	-	0.1	1.68; 3.62; 14.34	SBY-9	150
1426	body; light green with yellow weathering	1.9	1.2	0.2	0.33	SBY-9	210
1418h	body; light green with white weathering	2.2	1.6	0.2	0.45	SBY-9	150
621	-	-	-	-	-	-	-
1241	body; dark with dark grey weathering; 3 sherds (1 found with 1261)	5.2–7.4	2–6	0.2	2.82; 4.83; 11.72	SBY-7	6
1261	body; dark with dark grey weathering (probably same vessel as 1241)	7.2	3.4	0.3	12.09	SBY-7	7

***Appendix B**. EPMA results for the Ser Bani Yas glass sorted by group. Weight %. bdl = below detection limits (<0.03%). PbO, Sb_2O_3, SnO_2, CoO, NiO and ZnO are bdl for all samples and have been removed from the table.*

Sample	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CuO	SrO	BaO
Group 1	**Unknown Type**														
1483	14.64	3.59	3.34	60.58	0.34	0.25	0.80	1.78	12.10	0.23	0.04	1.16	bdl	0.09	0.03
1418b	14.77	3.66	3.39	61.11	0.27	0.32	0.81	1.86	12.08	0.24	0.04	1.02	0.17	0.12	bdl
1165b	15.25	3.99	4.34	59.61	0.40	0.22	0.89	1.87	11.38	0.29	0.05	1.70	0.03	0.11	bdl
1481a	15.39	3.91	3.45	59.52	0.35	0.28	0.49	2.18	11.15	0.20	1.07	1.18	bdl	0.09	bdl
1165a	15.13	3.96	4.37	59.45	0.40	0.21	0.90	1.86	11.21	0.28	0.05	1.70	bdl	0.09	bdl
1481f	15.27	3.93	3.44	59.55	0.32	0.30	0.47	2.18	11.07	0.20	1.07	1.15	bdl	0.13	bdl
1480d	14.89	3.88	3.43	61.37	0.40	0.19	0.86	2.14	10.66	0.24	0.04	1.32	bdl	0.11	bdl
1482a	17.96	3.86	3.57	58.11	0.30	0.36	0.56	2.12	10.43	0.21	0.06	1.25	bdl	0.10	bdl
1269	17.12	3.82	3.41	59.57	0.28	0.43	0.51	2.01	10.26	0.19	0.03	1.20	bdl	0.11	bdl
1417b	14.74	3.89	3.42	61.21	0.39	0.19	0.86	2.08	10.44	0.24	0.04	1.35	bdl	0.11	bdl
1245a	14.21	3.68	2.78	61.76	0.40	0.25	0.73	2.41	9.88	0.20	1.72	1.14	bdl	0.11	bdl
1480c	17.33	3.85	3.41	59.61	0.28	0.42	0.51	1.94	10.28	0.20	0.03	1.19	bdl	0.10	bdl
1201d	15.49	3.73	3.50	61.27	0.37	0.22	0.85	1.90	9.92	0.21	0.46	1.30	0.07	0.10	bdl
1201f	15.44	3.71	3.48	61.45	0.38	0.22	0.82	1.87	9.84	0.21	0.48	1.30	0.05	0.09	bdl
1221	14.92	3.91	3.44	61.38	0.40	0.19	0.84	2.14	10.37	0.24	0.05	1.38	bdl	0.09	bdl
1240	14.81	3.72	3.56	62.69	0.30	0.16	1.00	1.65	9.84	0.25	0.04	1.33	bdl	0.10	bdl
1417c	15.12	4.42	4.23	58.92	0.31	0.33	0.55	2.13	11.56	0.25	0.04	1.52	bdl	0.13	bdl
1201c	14.93	3.93	4.43	60.32	0.44	0.25	0.72	2.39	10.26	0.25	0.09	1.20	0.47	0.08	bdl
1175	14.77	3.75	3.63	62.77	0.31	0.15	1.03	1.66	9.77	0.24	0.04	1.37	bdl	0.13	bdl
1397a	15.16	4.45	4.25	58.95	0.31	0.31	0.60	2.19	11.37	0.26	0.04	1.50	bdl	0.09	bdl
1225b	15.10	4.45	4.26	58.68	0.35	0.29	0.58	2.18	11.37	0.24	0.04	1.52	bdl	0.10	bdl
1201b	15.15	4.00	4.48	60.31	0.36	0.27	0.68	2.37	10.20	0.27	0.09	1.66	bdl	0.08	bdl
1397b	15.19	4.43	4.21	58.79	0.30	0.30	0.60	2.15	11.25	0.26	0.04	1.48	bdl	0.10	bdl
1179	15.12	4.47	4.25	58.86	0.33	0.29	0.57	2.14	11.34	0.24	0.04	1.53	bdl	0.12	bdl
1201a	14.98	3.96	4.43	60.09	0.42	0.23	0.66	2.35	9.92	0.27	0.09	1.70	bdl	0.13	bdl
1263b	14.25	4.23	3.85	61.10	0.45	0.19	0.84	2.08	10.42	0.28	0.06	1.54	bdl	0.12	bdl
1258b	14.37	4.28	3.86	61.27	0.37	0.22	0.84	2.11	10.46	0.29	0.07	1.55	bdl	0.10	bdl
1481d	14.74	4.06	3.80	60.43	0.33	0.35	0.49	2.42	9.83	0.24	1.05	1.34	bdl	0.11	bdl
1417a	14.37	4.32	4.27	60.08	0.49	0.21	0.73	2.14	10.30	0.24	0.20	1.55	bdl	0.11	bdl
1481e	14.86	4.04	3.87	60.47	0.34	0.36	0.47	2.39	9.63	0.25	1.01	1.43	bdl	0.07	0.04
1480b	14.97	4.06	3.91	60.27	0.35	0.36	0.46	2.39	9.62	0.23	1.02	1.43	bdl	0.12	bdl
1418d	15.22	4.08	3.89	60.76	0.28	0.41	0.46	2.46	9.69	0.26	1.01	1.41	bdl	0.09	0.03
1481b	15.30	4.20	3.97	59.54	0.38	0.28	0.67	2.04	9.95	0.23	1.27	1.43	bdl	0.10	bdl
1480i	14.99	4.01	3.91	60.25	0.35	0.37	0.46	2.39	9.49	0.25	0.99	1.42	bdl	0.12	bdl
1420b	14.27	4.39	3.51	60.96	0.30	0.26	0.52	2.41	10.31	0.21	0.47	1.40	bdl	0.08	bdl
1249a	14.76	4.06	3.54	60.41	0.35	0.28	0.57	2.73	9.52	0.22	1.48	1.35	bdl	0.12	bdl
1423	15.28	4.21	3.94	59.43	0.39	0.26	0.64	2.04	9.79	0.23	1.31	1.44	bdl	0.09	0.04
1417d	15.29	4.24	3.97	59.63	0.39	0.28	0.66	2.07	9.78	0.23	1.24	1.42	bdl	0.12	0.03
1242a	15.01	4.07	2.96	61.60	0.33	0.22	0.54	2.75	9.11	0.18	0.74	1.26	0.04	0.12	bdl
1246b	15.14	4.08	2.97	61.73	0.32	0.23	0.57	2.78	9.19	0.18	0.75	1.29	0.04	0.12	bdl
1201e	15.05	4.09	2.99	61.34	0.34	0.23	0.56	2.78	9.15	0.19	0.73	1.30	0.04	0.11	bdl
1420c	15.44	3.66	3.78	62.69	0.23	0.36	0.66	3.02	8.03	0.20	0.03	1.24	bdl	0.10	0.03
1482b	14.28	3.48	4.74	60.81	0.47	0.32	0.37	2.71	9.68	0.27	0.06	1.63	bdl	0.09	bdl
1480g	14.55	3.85	5.03	60.23	0.41	0.23	0.59	2.66	9.32	0.30	0.05	1.88	bdl	0.07	bdl

1481c	14.62	3.87	5.04	60.68	0.37	0.24	0.59	2.64	9.27	0.31	0.05	1.91	bdl	0.08	bdl
1247	14.57	4.28	5.05	59.22	0.40	0.28	0.61	2.63	10.23	0.32	0.07	1.95	bdl	0.09	0.03
1263a	14.57	3.87	5.04	60.37	0.39	0.24	0.59	2.68	9.19	0.31	0.06	1.94	bdl	0.12	bdl
1418a	14.60	3.88	5.06	60.49	0.35	0.26	0.58	2.69	9.21	0.31	0.06	1.94	bdl	0.12	bdl
1443a	14.60	3.87	5.03	60.19	0.40	0.22	0.58	2.62	9.12	0.29	0.06	1.89	bdl	0.06	bdl
1166	14.59	3.85	5.03	60.49	0.40	0.24	0.59	2.70	9.04	0.30	0.06	1.97	bdl	0.11	0.04
1180b	14.57	4.31	5.04	59.06	0.46	0.24	0.59	2.58	10.00	0.32	0.07	2.00	bdl	0.09	bdl
Sample	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_3**	**Cl**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**Fe_2O_3**	**CuO**	**SrO**	**BaO**
Group 2	**Mesopotamian Type 1**														
G7b	15.29	4.28	2.53	63.23	0.27	0.23	0.78	2.68	8.35	0.15	0.20	1.02	0.14	0.12	bdl
1487	16.42	4.47	2.79	61.25	0.39	0.17	0.88	2.40	8.71	0.15	0.07	1.11	0.12	0.11	bdl
1424a	15.16	5.51	4.36	58.56	0.45	0.26	0.72	1.78	10.46	0.24	0.05	1.47	bdl	0.10	bdl
1422	15.42	5.54	4.03	59.07	0.35	0.38	0.47	2.48	10.44	0.24	bdl	1.18	bdl	0.10	bdl
1424b	16.28	4.33	2.93	61.55	0.37	0.26	0.90	2.84	8.10	0.19	0.12	1.17	bdl	0.11	bdl
G7a	15.32	4.32	2.04	63.93	0.18	0.17	1.12	2.43	8.04	0.15	0.97	0.62	bdl	0.11	0.04
1184	15.41	5.17	3.44	60.29	0.34	0.25	0.54	2.67	9.32	0.20	0.16	1.19	bdl	0.13	bdl
1444	16.26	4.28	3.30	62.21	0.32	0.23	0.80	2.68	7.71	0.19	0.12	1.20	bdl	0.11	bdl
1225a	15.32	4.58	2.34	63.21	0.30	0.21	0.70	2.90	8.17	0.14	0.26	0.77	0.21	0.11	bdl
1443b	17.00	4.85	2.65	58.60	0.31	0.27	0.74	3.74	8.55	0.15	0.59	1.02	bdl	0.10	bdl
1164	15.45	5.37	3.39	60.01	0.43	0.26	0.76	2.75	9.07	0.21	0.05	0.97	0.08	0.12	bdl
1245b	15.78	4.76	2.83	62.71	0.34	0.19	0.88	2.75	7.48	0.18	0.16	1.07	0.06	0.09	bdl
1245c	15.79	4.77	2.84	62.57	0.33	0.21	0.90	2.77	7.46	0.17	0.15	1.04	0.05	0.11	bdl
1258c	15.92	5.40	3.08	61.15	0.40	0.22	0.91	2.38	8.33	0.17	0.11	0.91	bdl	0.14	bdl
1225c	16.63	3.62	2.87	63.89	0.39	0.13	1.29	3.74	5.53	0.16	0.04	0.90	bdl	0.08	bdl
1299	13.96	5.61	2.49	62.54	0.27	0.15	0.82	3.06	8.45	0.14	0.72	0.74	bdl	0.13	bdl
1419b	15.89	5.05	2.93	63.22	0.29	0.20	1.03	2.36	7.44	0.15	0.04	0.89	bdl	0.11	0.03
1480a	17.42	4.45	3.48	59.91	0.27	0.26	0.75	4.07	6.45	0.13	0.98	0.93	bdl	0.10	0.03
1258a	15.68	6.14	2.71	60.25	0.25	0.31	0.66	3.19	8.75	0.15	0.07	0.83	bdl	0.14	bdl
Sample	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_3**	**Cl**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**Fe_2O_3**	**CuO**	**SrO**	**BaO**
Group 3	**Mesopotamian Type 2**														
1419c	16.35	5.58	1.64	64.20	0.16	0.25	0.87	2.63	6.77	0.08	0.07	0.56	0.03	0.11	bdl
1260	14.74	6.73	1.74	64.03	0.12	0.18	0.73	3.43	6.23	0.09	0.43	0.43	bdl	0.13	bdl
1246a	15.52	6.96	2.00	61.97	0.14	0.20	0.77	3.72	7.52	0.11	0.30	0.47	bdl	0.13	bdl
1228	15.47	6.84	2.06	61.92	0.16	0.21	0.68	3.52	6.96	0.10	0.38	0.38	0.16	0.14	bdl
1419d	14.73	6.11	2.22	63.16	0.18	0.17	0.67	3.04	7.54	0.14	0.44	0.65	bdl	0.14	bdl
1480f	14.78	5.77	1.34	66.48	0.11	0.17	1.03	1.79	7.27	0.06	bdl	0.42	bdl	0.08	bdl
1480h	14.66	5.72	1.35	66.24	0.12	0.15	1.01	1.75	7.11	0.06	bdl	0.42	bdl	0.11	bdl
1230	14.36	5.67	1.37	67.02	0.11	0.16	1.01	1.76	7.03	0.05	bdl	0.43	bdl	0.11	bdl
1480e	14.30	5.67	1.38	67.04	0.11	0.15	1.02	1.67	7.19	0.06	bdl	0.43	bdl	0.11	bdl
Sample	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_3**	**Cl**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**Fe_2O_3**	**CuO**	**SrO**	**BaO**
Group 4	**Unknown (local?) Type**														
1447	14.99	3.87	1.49	64.45	0.24	0.12	0.94	2.69	9.27	0.07	0.06	0.70	bdl	0.14	bdl
1426	15.14	3.89	1.54	64.23	0.24	0.12	0.92	2.73	9.15	0.07	0.06	0.61	0.25	0.14	bdl
1418h	15.07	3.92	1.55	64.54	0.22	0.14	0.96	2.73	9.12	0.08	0.07	0.70	0.08	0.14	bdl
621	14.28	4.13	1.79	65.60	0.24	0.15	0.55	2.13	9.22	0.11	0.06	0.99	0.09	0.10	bdl
1241	15.55	3.64	1.90	62.39	0.29	0.20	0.43	2.50	9.53	0.12	1.39	0.85	bdl	0.17	bdl
1261	15.64	3.65	1.91	62.44	0.28	0.22	0.46	2.51	9.61	0.12	1.40	0.83	bdl	0.11	0.03