Journal of Archaeological Science: Reports 48 (2023) 103841

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Glass from the Silk Roads. Insights into new finds from Uzbekistan

Tania Chinni [a,*], Sara Fiorentino [a], Alberta Silvestri [b], Simone Mantellini [c], Amriddin E. Berdimuradov [d], Mariangela Vandini [a]

[a] Department of Cultural Heritage, University of Bologna – Ravenna Campus, via degli Ariani 1, 4821 Ravenna, Italy
[b] Department of Geosciences, University of Padua, via G. Gradenigo 6, 35131 Padua, Italy
[c] Department of History and Cultures, University of Bologna – Ravenna Campus, via San Vitale 28-30, 48121 Ravenna, Italy
[d] Institute of Archaeology of Samarkand, Ministry of Tourism and Cultural Heritage, street Adbullaev 3, 140061 Samarkand, Uzbekistan

ARTICLE INFO

Keywords:
Archaeological glass
Silk Roads
Uzbekistan
EPMA
LA-ICP-MS

ABSTRACT

The paper provides insights into an assemblage of glass finds from the citadel of Kafir Kala and the site of Cholaktepa both in the proximity of Samarkand (Uzbekistan). Located along one of the major Eurasian branches of the Silk Roads, passing through Samarkand, Kafir Kala is among the most relevant centres to better understand the Islamization of the Middle Zeravshan Valley in the early 8th century. During the excavations, hundreds of fragments of ceramics, and a conspicuous amount of glass finds were recovered. Chrono-typological study allowed identifying objects for everyday use like bottles, cups with handles and bowls with re-folded rims; fragments of decorated bottoms with a honeycomb pattern, showing a distinctive rosette stamp, were also identified. Moreover, glass debris from Cholaktepa, 11 km west of nowadays Samarkand, provided evidence for the occurrence of glass working. Compositional analyses, by electron microprobe (EPMA) for major and minor elements and by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) for trace elements, have been carried out on selected fragments, aimed at investigating the compositional features of finds and their raw materials, to establish comparisons with published assemblages pertinent to neighbouring geographical areas and comparable chronological spans. All the glass fragments are silica-soda-lime in composition, made by using plant ash as fluxing agent, except two samples made by using natron. Compositional data show a link to the Ferghana Valley in Uzbekistan, where a local glass manufacture has been identified.

1. Introduction

Providing a chronological and geographical definition of the interconnected web of routes commonly known as Silk Roads is not a simple task. The network of multiple ways that linked by land and sea the ancient Asian and Mediterranean societies reached its peak during the Han Dynasty and the Kushan Empire, in the first centuries BCE and CE. However, the origin of this phenomenon can be framed even earlier in the material and cultural exchanges of nomads and semi-mobile pastoralism groups across Eurasia (Benjamin, 2018). In the pre-Islamic centuries, a crucial role in the long-term commercial activity between Central Asia and China was played by the Sogdian merchants, who originated in the region of Samarkand (de la Vaissière, 2005). As discussed in greater depth elsewhere (Williams, 2014), movements along and across the Silk Roads were complex, with a great variety of goods and people flowing from east to west and vice versa. Furthermore, the movement of goods and the volume of exchange had a massive impact on many of the societies along the Silk Roads: it shaped their ability to build the famous cities, religious buildings, and elite structures. The spread of religions, social customs, languages, political ideas, agricultural practises, scientific knowledge, know-how, and technological innovations was the most significant outcome of these complex networks of interactions. In such a diverse environment, little is currently known about glass and its movements. As demonstrated by our study, the main question concerning the identification of production centres cannot be answered without understanding how trade and routes changed over time, also as a consequence of the changes connected with the Arab conquest of the Samarkand region in the early 8th century. Located in a strategic position that controlled one of the local north–south passages along the ancient Silk Road, the archaeological complex of Kafir Kala (site code Sam-090) is about 12 km southeast of Afrasiab, the ancient city of Samarkand (Mantellini and Berdimuradov, 2005) (Fig. 1). The

* Corresponding author.
E-mail addresses: tania.chinni2@unibo.it (T. Chinni), sara.fiorentino2@unibo.it (S. Fiorentino), alberta.silvestri@unipd.it (A. Silvestri), simone.mantellini@unibo.it (S. Mantellini), uzarchae@mail.ru (A.E. Berdimuradov), mariangela.vandini@unibo.it (M. Vandini).

https://doi.org/10.1016/j.jasrep.2023.103841
Received 27 September 2022; Received in revised form 28 December 2022; Accepted 12 January 2023
Available online 21 January 2023
2352-409X/

sites of Kafir Kala and Cholaktepa have been the subject of targeted investigations as part of the Uzbek-Italian Archaeological Project – UIAP "Samarkand and Its Territory" (Mantellini and Berdimurodov, forthcoming).

A network combining artificial and natural waterways had ensured the defence of the complex over ca. 30 ha, making Kafir Kala the second largest site in this area after Afrasiab. The site is built with rammed earth and it is shaped by different architectural features (Fig. 2a,b). A square citadel, ca. 60 by 60 m, is in the middle of a moat that is surrounded by a residential area (*shahristan*). At West, a second moat separates the main complex from an outer settlement (*rabad*). The reclamation activities of the last decades largely flattened a necropolis outside the southern *shahristan* and an artisan district on the right bank of the Ilonsai with many pottery kilns, both only partially investigated in the late 30 s-early 40 s of the 19th century (Berdimuradov and Mukhammadiev, 2016; Grigorev, 1940).

The early occupation (late 7th–early 8th centuries) refers to the years immediately preceding the Islamic conquest of Samarkand in 712. The monumentality of the site, its architecture, its proximity to Samarkand, and the exceptional finds discovered there, suggested the identification of Kafir Kala with Rēwdād, mentioned by the Arab geographer Istakhri as the rural residence of the pre-Islamic kings (*ikhshid*) of Samarkand (Grenet and de La Vaissière, 2022). The end of this occupation phase is well recognizable in the archaeological record by a thick layer of burnt wooden beams and column bases belonging to a porch running around the inner courtyard. The presence in this layer, and in the compact beaten earthen floor below it, of coins dated to Tarkhun, the last *ikhshid* of Samarkand (700–710 CE), make possible framing the fire exactly at the time of the arrival of Islam in 712 CE (Gariboldi et al., 2018; Usami et al., 2017). The fire that caused the dramatic end of the citadel of Kafir Kala is a further indication on the political importance of this site, as arguable from the present toponym "Kafir Kala" that means "Fortress/Castle of unbelievers" in Arabic. Following a temporary abandonment, the site was immediately resettled for residential purposes already in the early 8th century. Compared to the previous period, this occupation is marked by a rough architecture, with the systematic reuse and adaptation of previous architectural structures and spaces (di Cugno et al., 2013). The long corridor (ca. 45 m) along the western side, for example, was turned into a residential room (Room 7), a small storage (Room 10), a kitchen (Room 11), and a large storage area in the circular corner tower (Room 14), whereas the southern part was left unused (Mantellini et al., 2016). The use of the space for domestic activities is emphasized by the remains of dozens of fire structures (*tandir*/domed ovens, fireplaces, hearths), as well as a significant amount of pottery. Around the 12th century, the citadel was definitively abandoned.

Among the unearthed finds, coins (Gariboldi et al., 2018) and glass are the most numerous and important in terms of understanding the Islamic transition that this settlement underwent. The glass finds selected for this study belong to the three main contexts described above (pre-Islamic, early Islamic and abandonment of the citadel). Another set of glass comes from Cholaktepa, site code Sam-105, 11.5 km West of Samarkand/Afrasiab and 21 km NW of Kafir Kala. The site was identified on the 25,000 topographical maps and then validated on the field in 2007 and 2009. The exposed section at west evidenced the presence of a fireplace and burnt layers in the archaeological stratigraphy. In the middle of the site, a S—N trench disclosed several sherds of glazed pottery and a few fragments of glass. The discovery of glass during surface survey is rather unusual in Samarkand, since it is attested only in 21 over ca. 2,300 sites (ca. 1 %). Moreover, glasses from Cholaktepa are remarkable for two reasons: first, this is the only site with certain production wastes; secondly, the chronology is like Kafir Kala, with a significant occupation in the Medieval period (9th-12th centuries AD).

The present study is related to one that was recently published by the authors on a selection of glass finds from the same archaeological context (Fiorentino et al., 2021). The focus is here on the chrono-typological study of fragments attributable to specific shapes, combined with chemical analysis to define the raw materials used and establish possible connections with previously investigated assemblages

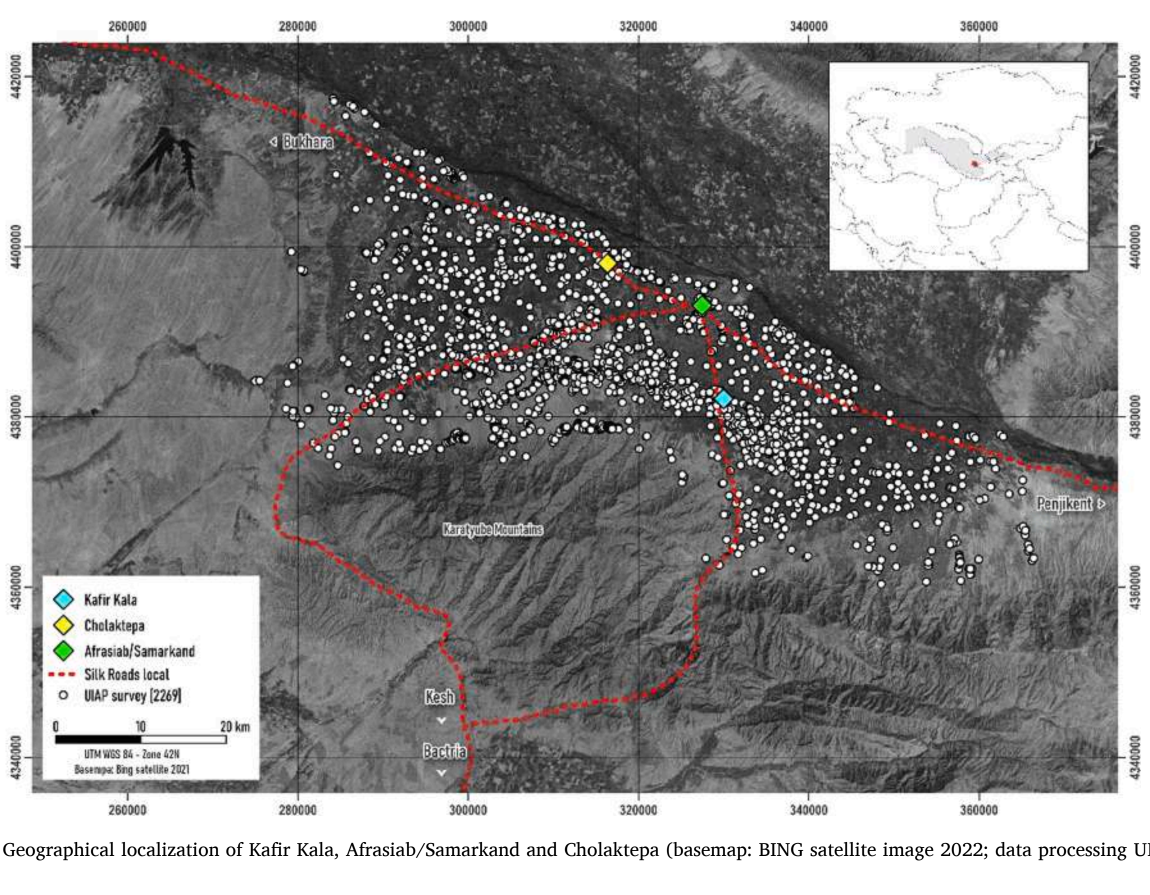


Fig. 1. Geographical localization of Kafir Kala, Afrasiab/Samarkand and Cholaktepa (basemap: BING satellite image 2022; data processing UIAP ©).

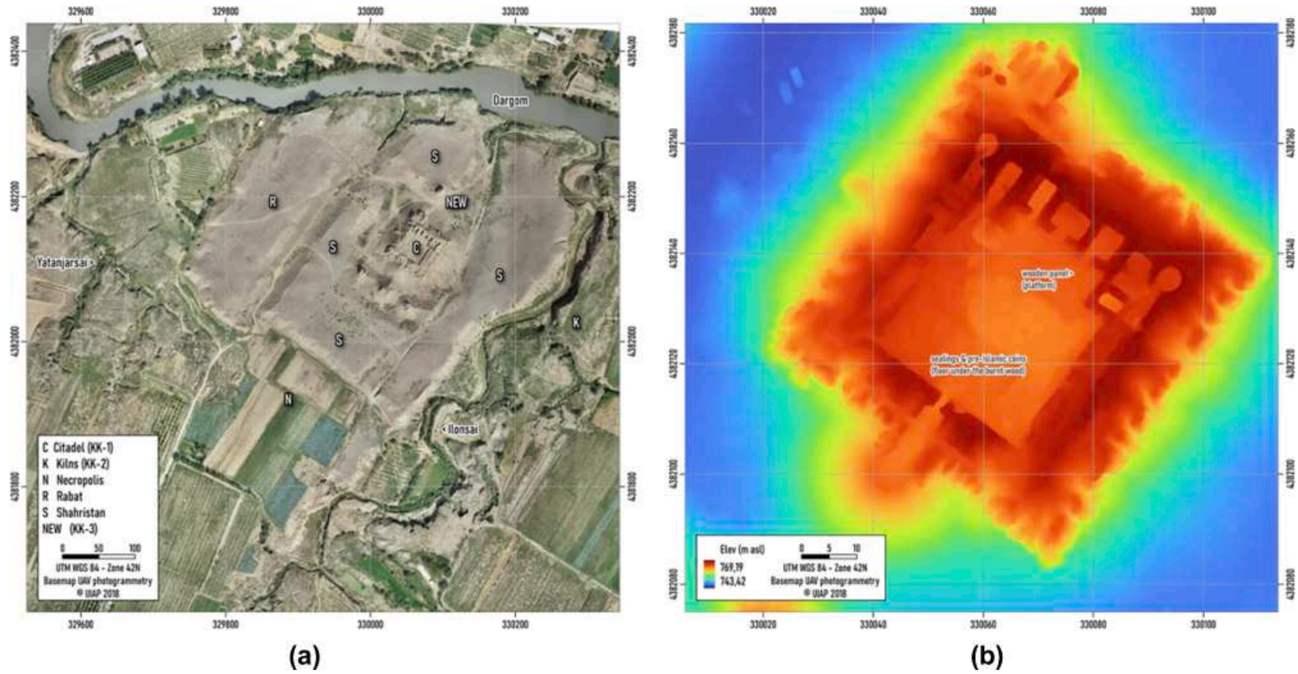


Fig. 2. A) architectural features of the site; b) digital terrain model of the citadel of kafir kala, 7th-14th century (uav data acquisition and processing uiap ©).

of finds from sites located in the same region.

2. Materials and methods

A total of 329 glass fragments were found inside the citadel of Kafir Kala, mainly datable to the pre-Islamic and early Islamic phases of the site. The citadel was burnt in 712 CE, during the Arab conquest, *terminus post quem* for the Islamic settlement. Among the unearthed finds, 291 were classified as undecorated walls, the majority being highly compromised by severe surface degradation phenomena, discussed elsewhere (Fiorentino et al., 2021); 38 fragments of rims, bottoms and handles were identified.

The research presented in this article was carried out on 11 fragments of undecorated walls chosen from those least compromised by surface degradation (KK-d1, KK-d2, KK-d3, KK-d4, KK-d5, KK-d6, KK-d7, KK-d8, KK-d9, KK-d11, KK-d14), as well as 18 fragments attributable to rims (KK-r1, KK-r2, KK-r3, KK-r4, KK-r5, KK-r6, KK-r7, KK-r8, KK-r9), bottoms (KK-b1, KK-b2, KK-b3, KK-b4, KK-b5) and handles (KK-h1, KK-h2, KK-h3, KK-h4).

4 glass working debris (SAM-GD1, SAM-GD2, SAM-GD3, SAM-GD4) from Cholaktepa, and 2 walls of vessels (SAM-W1, SAM-W2) were also investigated. All selected finds, for a total of 35 samples, are reported in Table 1.

Photographic documentation, technical drawings, and documentation of the chromatic hues by NCS Colour System, as well as comparisons with literature data, were used to conduct a chrono-typological study on fragments of rims, bottoms, handles from Kafir Kala (Figure S4) and on glass debris and walls of vessels from Cholaktepa.

Quantitative chemical analyses, aimed at acquiring data on major and minor elements characterising the base glass composition, were carried out by using electron microprobe (EPMA). The EPMA employed was a JEOL 8200 Super Probe, equipped with five WDS spectrometers and located at the Department of Earth Sciences of the University of Milan "La Statale". Analytical conditions, used for glass samples from Kafir Kala and Cholaktepa, are detailed into Table S1a, provided as supplementary materials; it should be also stressed here that the electron beam was de-focussed to about 10 µm, in order to reduce alkali volatilisation. Accuracy of EPMA measures was checked against the international reference standards, Corning glasses A, B and D, and was lower than 1 % for SiO_2, Na_2O, and CaO, lower than 5 % for K_2O, MgO, P_2O_5, Fe_2O_3 and Sb_2O_3, and within 10 % for other minor elements (Table S1b). The chemical compositions of the Kafir Kala and Cholaktepa glasses were identified by about six point microanalyses for sample, and averages and standard deviations were calculated. EPMA data are provided in Table S2.

Laser Ablation–Inductively Plasma Coupled–Mass Spectrometry (LA–ICP–MS) was performed to determine the concentration of trace elements. Analyses were carried out at the University of Modena and Reggio-Emilia (Italy) by a Thermo Fisher X-Series II quadrupole based ICP–MS coupled with a New Wave ablation system with a frequency quintupled ($\lambda = 213$ nm) Nd:YAG laser. Laser parameters were the following: spot-size 80 µm; frequency 10 Hz; dwell time 40 s; energy density ~ 8 J/cm^2. Helium was used as carrier gas, with a flow of 0.6 L/min; the frequency of standard analysis was every 20 measurement points. Data reduction was carried out following Longerich and colleagues (Longerich et al., 1996); ^{29}Si was employed as an internal standard, NIST 612 as external reference material. The distribution of REE and of the other trace elements was analysed by normalising the data to the upper continental crust (Kamber et al., 2005). Accuracy of LA-ICP-MS measures checked against the international reference standards is provided in Table S1b; LA-ICP-MS data are provided in Table S3.

To avoid any contamination ascribable to the altered surface, micro-samples (of the order of few square millimetres) were taken from the core of the selected fragments. To perform EPMA and LA-ICP-MS analyses, the glass micro-samples were embedded in blocks of resin, covered by a thin carbon layer (only for EPMA).

3. Results and discussion

3.1. Chrono-typological study

The chrono-typological study on fragments of rims, bottoms, and handles from Kafir Kala and chosen for the chemical analyses had identified and confirmed the presence of typologies ascribable between the 7th and 12th centuries AD, when the new Arab domination definitively assimilated the pre-existing administrative structures. The KK-r1 and KK-r2 fragments appear as slightly funnel-shaped rims, straight and indistinct by the wall. Because of the small size, they can be

Table 1
Kafir Kala - Rims, bottoms and handles.

Kafir Kala – Rims, bottoms and handles									
Sample	**Photo**	**SU**	**Archaeological phase**	**Object**	**Typology**	**Dating form**	**Colour**	**NCS codex**	**References**
KK-r1		KK1 2013 SU 683	Pre-Islamic	cut-off rim	small bottle / perfume bottle	8th-11th cent. AD	Light olive green	S 1015-G80Y	Gorin-Rosen 2010, n. 4, pl. 10.5 (Abbasid period); Foy 2012, n. 56, pl. 20 (Umayyad period); Ouahnouna 2018, n. 11, Fig. 2 (Abbasid period)
KK-r2		KK1 2005 SU 5	Islamic	Cut-off rim	small bottle or perfume bottle	8th-11th cent. AD	Light olive green	S 2030-G40Y	Gorin-Rosen 2010, n. 4, pl. 10.5 (Abbasid period); Cullen 2009, PF 22, p. 239 (9th-10th cent.)
KK-r3		KK1 2008 SU 339 (room 12)	Islamic	infolded rim	Globular bottle	Mid-7th-mid 8th cent. AD	Light blue	S 1005-B20G	Hadad 2005, nn. 182–184, pl. 9 – nn. 185–190, pl. 10 – nn. 191–195, pl. 11 (Umayyad period); Pollak 2007, n.62, fig. 10 (Umayyad period); Gorin-Rosen 2010, n. 13, pl. 10.1 (Umayyad period)
KK-r4		KK1 2005 SU 1	Islamic	Inverted rim	bottle	7th-11th cent. AD	Emerald green	S 7020-G	Bass 1984, *h*, pag. 68 (mid-11th cent.); Hadad 2005, n. 187 (Umayyad period); Ouahnouna 2018, n. 7, Fig. 2 (9th-11th cent.); Ouahnouna 2020, n.7, Fig. 3 (Abbasid period);
KK-r5		KK1 2013 SU 645 (room 18)	Islamic	Vertical rim	Beaker	Byzantine period or 9th-10th cent. AD	Aqua green	S 1020-B30G	Pollak 2007, n. 26, Fig. 6 (byzantine period) or Pollak 2007, n. 46, fig. 8 (9th-10th cent.)

(*continued on next page*)

Table 1 (*continued*)

Kafir Kala – Rims, bottoms and handles									
Sample	**Photo**	**SU**	**Archaeological phase**	**Object**	**Typology**	**Dating form**	**Colour**	**NCS codex**	**References**
KK-r6		KK1 2006 SU 2 W	Islamic	Refolded rim	Bowl	Mid-4th – 9th cent. AD	Aqua green	S 1020-B30G	Dussart 1998, BI. 4122 (mid-4th – 8th cent.); Hadad 2005, nn. 49–50 (Umayyad period) and nn. 561–563 (Abbasid/ Fatimid period); Israeli 2008, nn. 78–81 (4th-5th cent.); Pollak 2007, n. 7, Fig. 1 (8th cent.)
KK-r7		KK1 2006 SU 2 W	Islamic	Tubular rim	Bowl	Mid-4th – 9th cent. AD	Aqua green	S 1515-B80G	Dussart 1998, BI. 4122 (mid-4th – 8th cent.); Hadad 2005, nn. 60–61 (Umayyad period) and nn. 561–563 (Abbasid/ Fatimid period); Israeli 2008, nn. 78–81 (4th-5th cent.)
KK-r8		KK1 2006 SU 2 W	Islamic	Tubular rim	Bowl	Mid-4th – 9th cent. AD	Aqua green	S 1515-B80G	Dussart 1998, BI. 4122 (mid-4th – 8th cent.); Hadad 2005, nn. 60–61 (Umayyad period) and nn. 561–563 (Abbasid/ Fatimid period); Israeli 2008, nn. 78–81 (4th-5th cent.)
KK-r9		KK1 2006 SU 2 W	Islamic	Tubular rim	Bowl	Mid-4th – 9th cent. AD	Aqua green	S 1515-B80G	Dussart 1998, BI. 4122 (mid-4th – 8th cent.); Hadad 2005, nn. 60–61 (Umayyad period) and nn. 561–563 (Abbasid/ Fatimid period); Israeli 2008, nn. 78–81 (4th-5th cent.)
KK-b1		KK1 2006 SU 2 W	Islamic	Flat bottom with pontil mark	Large bottle	from 7th to mid-13th cent. AD	Aqua green	S 3555-B60G	Hadad 2005, n. 219 (Umayyad period), n. 885 (Abbasid/ Fatimid period) and n. 1088 (Abbasid/ Mamaluk period)

(*continued on next page*)

Table 1 (*continued*)

Kafir Kala – Rims, bottoms and handles									
Sample	**Photo**	**SU**	**Archaeological phase**	**Object**	**Typology**	**Dating form**	**Colour**	**NCS codex**	**References**
KK-b2		KK1 2006 SU 2 W	Islamic	Flat bottom with rosetta stamp and honeycomb pattern	Bowl or bottle	10th – 11th cent. AD	Light green	S 1515-G	Bass 1984, *c* and *e*, pg. 68 [without rosette stamp] (1st half of 11th cent.); Hadad 2005, nn. 595–596, pl. 30 (mid 8th-11th cent.); Pollak 2007, nn. 66 and 69, pl. 10 (10th-11th cent.); Gorin-Rosen 2010, Pl. 10.9:2 (10th-11th cent.)
KK-b3		KK1 2008 SU 442 (room 14)	Islamic	Flat bottom with rosetta stamp and honeycomb pattern	Bowl or bottle	10th – 11th cent. AD	Light blue	S 5020-B90G	Bass 1984, *c* and *e*, pg. 68 [without rosette stamp] (1st half of 11th cent.); Hadad 2005, nn. 595–596, pl. 30 (mid 8th-11th cent.); Pollak 2007, nn. 66 and 69, pl. 10 (10th-11th cent.); Gorin-Rosen 2010, Pl. 10.9:2 (10th-11th cent.)
KK-b4		KK1 2008 SU 1 W	Islamic	Flat bottom with rosetta stamp and honeycomb pattern	Bowl or bottle	10th – 11th cent. AD	Aqua green	S 6020-B90G	Bass 1984, *c* and *e*, pg. 68 [without rosette stamp] (1st half of 11th cent.); Hadad 2005, nn. 595–596, pl. 30 (mid 8th-11th cent.); Pollak 2007, nn. 66 and 69, pl. 10 (10th-11th cent.); Gorin-Rosen 2010, Pl. 10.9:2 (10th-11th cent.)
KK-b5		KK1 2005 SU 5	Islamic	Flat bottom	Small bottle	7th-8th cent. AD	Light green	S 2030-G40Y	Hadad 2005, n. 140 (Umayyad period)

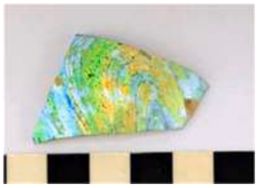
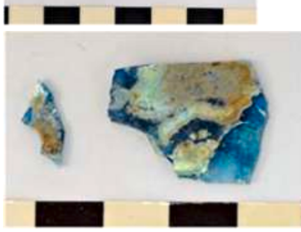
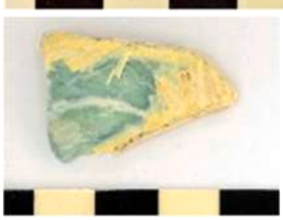
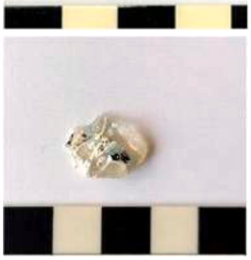
(*continued on next page*)

Table 1 (*continued*)

Sample	Photo	SU	Archaeological phase	Object	Typology	Dating form	Colour	NCS codex	References
Kafir Kala – Rims, bottoms and handles									
KK-h1		KK1 2005 SU 1	Islamic	Loop handle	Cup	8th – mid 12th cent. AD	Light blue	S 2040-B20G	Davidson 1987, n. 724 (11th - mid 12th cent.); Hadad 2005, n. 938 (Abbasid/ Fatimd period); Jennings 2006, n. 3, fig. 8.13 (undated context); Matthews and Lledó 2009, HN 16, Fig. 39-3 (mid. 9th cent.)
KK-h2		KK1 2008 SU 266 (room 11)	Islamic	Loop handle with decoration?	Bottle or lamp	mid 7th – 12th cent. AD	Light blue	S 4550-B90G	Hadad 2005, nn. 389–393 (Umayyad period) and nn. 927–933 (Abbasid/ Fatimid period)
KK-h3		KK1 2013 SU 665 (central trench)	Islamic	Loop handle with thumb-rest	Cup	8th – mid 12th cent. AD	Light blue	S 3040-B10G	Davidson 1987, n. 724 (11th - mid 12th cent.); Hadad 2005, n. 938 (Abbasid/ Fatimd period); Jennings 2006, n. 3, fig. 8.13 (undated context); Matthews and Lledó 2009, HN 16, Fig. 39-3 (mid. 9th cent.)
KK-h4		KK1 2006 SU 1 W	Islamic	Loop handel	Cup	8th – mid 12th cent. AD	Light blue	S 0515-B20G	Davidson 1987, n. 724 (11th - mid 12th cent.); Hadad 2005, n. 938 (Abbasid/ Fatimd period); Jennings 2006, n. 3, fig. 8.13 (undated context); Matthews and Lledó 2009, HN 16, Fig. 39-3 (mid. 9th cent.)
Kafir Kala – Undecorated walls									
Sample	**Photo**	**SU**	**Archaeological phase**	**Object**	**Typology**	**Dating form**	**Colour**	**NCS codex**	**References**
KK-d1		KK1 2006 SU 1 E	Islamic	wall	undefined	*Not applicable*	Blue	S 4040-R80B	*Not applicable*

(*continued on next page*)

Table 1 (*continued*)

Kafir Kala – Rims, bottoms and handles									
Sample	**Photo**	**SU**	**Archaeological phase**	**Object**	**Typology**	**Dating form**	**Colour**	**NCS codex**	**References**
KK-d2		KK3 2003 SU 125	Timurid	Wall	undefined	*Not applicable*	Green/ Yellow	S 0530-G20Y	*Not applicable*
KK-d3		KK1 2008 SU 345 (room 13)	Islamic	Wall	undefined	*Not applicable*	Aquamarine	S 0530-B10G	*Not applicable*
KK-d4		KK1 2001 SU 11	Islamic	Wall	undefined	*Not applicable*	Light blue	S 0530-B40G	*Not applicable*
KK-d5		KK1 2006 SU 1 W	Islamic	Wall	undefined	*Not applicable*	Blue	S 1555-B10G	*Not applicable*
KK-d6		KK1 2013 SU 683	Pre-Islamic	Wall	undefined	*Not applicable*	Light blue	S 2020-B40G	*Not applicable*
KK-d7		KK1 2013 SU 683	Pre-Islamic	Wall	undefined	*Not applicable*	Light blue	S 2020-B40G	*Not applicable*
KK-d8		KK1 2013 SU 646	Islamic	Wall	undefined	*Not applicable*	colourless	S 2005-G80Y	*Not applicable*
KK-d9		KK1 2005 SU 5	Islamic	Wall	undefined	*Not applicable*	*Unevaluable*	*Not valuable*	*Not applicable*

(*continued on next page*)

Table 1 (*continued*)

Sample	Photo	SU	Archaeological phase	Object	Typology	Dating form	Colour	NCS codex	References
Kafir Kala – Rims, bottoms and handles									
KK-d11		KK1 2005 SU 7	Islamic	Wall	undefined	*Not applicable*	Colourless	S 2005-G80Y	*Not applicable*
KK-d14		KK1 2001 SU 6	Islamic	wall	undefined	*Not applicable*	Green	S 2050-G30Y	*Not applicable*
Cholakpeta – Working debris and undecorated walls									
Sample	**Photo**	**SU**	**Archaeological phase**	**Object**	**Typology**	**Dating form**	**Colour**	**NCS codex**	**References**
SAM-GD1		2009 SAM 105	Islamic	Glass chunk	*Not applicable*	*Not applicable*	Dark green	S 6030-G	*Not applicable*
SAM-GD2		2009 SAM 105	Islamic	Glass chunk	*Not applicable*	*Not applicable*	Dark green	S 6030-G	*Not applicable*
SAM-GD3		2009 SAM 105	Islamic	Glass chunk	*Not applicable*	*Not applicable*	Dark green	S 6030-G	*Not applicable*

(*continued on next page*)

Table 1 (*continued*)

Kafir Kala – Rims, bottoms and handles									
Sample	**Photo**	**SU**	**Archaeological phase**	**Object**	**Typology**	**Dating form**	**Colour**	**NCS codex**	**References**
SAM-GD4		2009 SAM 105	Islamic	Fluidity proof (drop)	*Not applicable*	*Not applicable*	Green	S 4030-B90G	*Not applicable*
SAM-W1		2009 SAM 105	Islamic	wall	*Not applicable*	*Not applicable*	Purple	S 6030-R	*Not applicable*
SAM-W2		2009 SAM 105	Islamic	wall	*Not applicable*	*Not applicable*	Blue	S 3560-R80B	*Not applicable*

identified as small bottles or perfume bottles. The irregularity of their shape suggests that they are ordinary products, not designed to meet the needs of the élite. The glass appears to be naturally coloured, full of air bubbles, and heavily altered by post-depositional processes. Similar specimens can be found in the Israeli city of Ramla, in layers dating back to the end of the 10th century (Gorin-Rosen, 2010; Ouahnouna, 2018), in the Umayyad contexts of al-Hadir (Syria) (Foy, 2012), and in the 11th century marine wreck of Serçe Limani (Turkey) (Cullen, 2009). The KK-r3 rim is an everted and folded inwards rim from a bottle with a globular body. The archaeologists recovered and partially reconstructed the artefact, which was made of opaque light blue glass that had become highly degraded. The find can be compared to Umayyad materials from Ramla (Gorin-Rosen, 2010; Pollak, 2007) and Bet Shean's so-called *suq* of Hishām, dated to the same period (Hadad, 2005). The KK-r4 fragment is an inverted emerald glass rim that is commonly found on small or large bottles. Although similar rims have been found since the Umayyad period (Hadad, 2005), they can also be found in early Islamic assemblages in the Ramla train station (Ouahnouna, 2018), in the Abbasid strata of Jaffa (Ouahnouna, 2020), and in the Serçe Limani underwater relic from the mid-11th century (Bass, 1984). The KK-r5 is made of pale aqua green glass and has a slightly everted profile. The preserved fragment is too small to be associated with a specific typology, but among the comparisons available in the literature, the two most appropriate come from the excavation of Marcus Street in Ramla (Pollak, 2007), and refer to a Byzantine period stemmed goblet or a 9th-10th century jar. KK-r6, KK-r7, KK-r8, and KK-r9 are rims of bowls made of pale green glass. They are folded towards the outside; the walls are slightly convex. Similar finds have been found in Caesarea Maritima, in association with 4th-5th century coins (Israeli, 2008), in Jordan and southern Syria, in contexts dated from the 4th to the 8th centuries (Dussart, 1998), in Ramla (Pollak, 2007), and in Bet Shean (Hadad, 2005), in contexts from the 8th century. The KK-b1 is a light green flat bottom. The fragment shows the pontil mark: a distinguishing feature associated with the free-blowing technique. Despite the lack of additional distinguishing features, the dimensions and appearance of the fragment KK-b1 can be compared with large bottlesfound in Umayyad contexts, as well as Abbasid/Fatimid and Mamaluk phases, in Bet Shean's so-called *suq* of Hishām (Hadad, 2005). Flat light green glass bottoms with a mould blown honeycomb decoration and a central rosette's stamp are KK-b2, KK-b3 and KK-b4. In comparison to the KK-b1 bottom, they can identified thanks to the decoration. This feature appears in association with bowls or bottles dated back to the Abbasid and Fatimid periods in several Middle Eastern contexts, like the cargo of Serçe Limani (Bass, 1984), Bet Shean (Hadad, 2005), and Ramla (Gorin-Rosen, 2010; Pollak, 2007). KK-b5 has a recessed profile and a pontil mark on the bottom surface. The severely deteriorated fragment is compatible with a small globular bottle. A comparison can be found in the Umayyad contexts of Bet Shean (Hadad, 2005). Loop handles, with or without thumb rest, are represented by samples KK-h1, KK-h3, and KK-h4. They are commonly associated with cups or pendant lamps, as well as long-necked bottles. Very similar comparisons can be found in the assemblies of the South Agora of Corinth (Turkey), dating from the 11th - mid-12th century (Davidson, 1987), the so-called *suq* of Hishām in Bet Shean (Hadad, 2005), the souk of Beirut (Jennings, 2006), and among the products of the Serçe Limani shipwreck (Matthews and Lledó, 2009). The KK-h2 is very similar to the previous handles but shows a glass extension that has

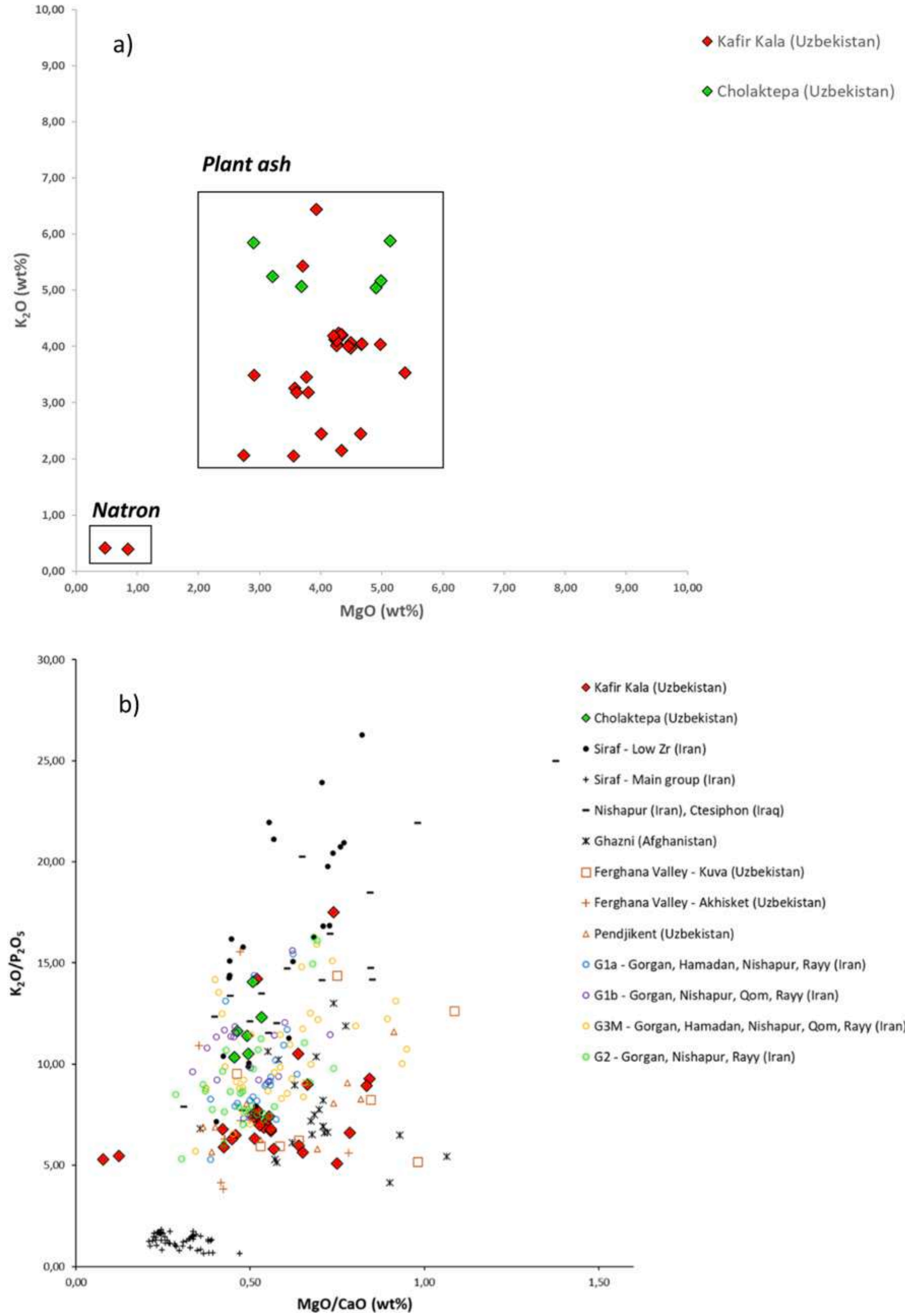


Fig. 3. A) k_2O versus MgO scatter plot, with reference values for natron and plant ash glass and b) K_2O/P_2O_5 versus MgO/CaO scatter plot with comparison with data from the literature for plant ash-based glass from Central Asia (Abdurazakov, 1969; Bezborodov and Abdurazakov, 1964; Brill, 2009; Fiorentino et al., 2019; Henderson et al., 2016; Rehren et al., 2010; Schibille et al., 2022; Swan et al., 2017).

been flattened and extended to cover the intersection area between the loop and the wall. The object to which this fragment belongs has not been identified, but extending the handle (downwards or upwards) is common in some typologies of lamps and bottles, as demonstrated by Umayyad and Abbasids/Fatimids assemblages in Bet Shean (Hadad, 2005). Samples KK-d1, KK-d2, KK-d3, KK-d4, KK-d5, KK-d6, KK-d7, KK-d8, KK-d9, KK-d11, and KK-14 are wall fragments with no significant characteristics that help to defined the original typologies. Six glass objects from Cholaktepa, 11 km from the citadel of Kafir Kala, completed the dataset. The samples are distinguished between raw glass chunks (SAM-GD1, SAM-GD2, SAM-GD3), fluidity tests (SAM-GD4), and two fragments of vessel (SAM-W1, SAM-W2).

3.2. Compositional study

The finds from Kafir Kala and Cholaktepa are all of a soda-lime-silica glass type (Fig. 3a). All but two samples (KK-d8 and KK-d11) have K_2O contents between 2.06 wt% and 6.44 wt% and MgO between 2.74 wt% and 5.38 wt%, consistent with the use of halophytic plant ash as fluxing agent. Samples KK-d8 and KK-d11 are characterised by lower K_2O and MgO contents, falling within the range of natron-based glass (KK-d8: $K_2O = 0.40$ wt% and $MgO = 0.85$ wt%; KK-d11: $K_2O = 0.41$ wt% and $MgO = 0.48$ wt%).

Regarding the plant as-based glasses, the samples can be further classified into two sub-groups (Fig. 3b). The finds from Kafir Kala (all but KK-d2 and KK-d5) belong to the first sub-group, comparable with assemblages from Ghazni, Afghanistan (Fiorentino et al., 2019) and Kuva, Akhsiket and Pendjikent, Uzbekistan (Abdurazakov, 1969; Bezborodov and Abdurazakov, 1964; Brill, 2009; Rehren et al., 2010). The second sub-group, which encompasses all the samples from Cholaktepa and two samples from Kafir Kala's citadel (KK-d2, KK-d5), shows comparability with Siraf Low Zr Group (Swan et al., 2017) and assemblages from Iranian sites (Schibille et al., 2022). According to major oxide data, the usage of two different plant ashes can be hypothesised.

For a further comparison with data from the literature, Al_2O_3 versus MgO/CaO scatterplot was selected, as recent research has outlined relevant compositional variations in major and minor oxides (especially K_2O, MgO, CaO and Al_2O_3) moving East-West across Central Asia: plant ash glasses from eastern regions tend to have higher MgO/CaO ratio and higher MgO than glasses from Syria-Palestine (Freestone, 2006; Henderson et al., 2016; Phelps, 2018; Simpson, 2014). Fig. 4 shows that most of the samples from Kafir Kala fall in the upper part of the diagram; among them, only a few (KK-d14, KK-r2, KK-b5, KK-d3, KK-d6, KK-d7) more consistently match the so-called Mesopotamian Type II compositional group, encompassing: Sasanian plant ash-based glasses from Veh Ardašīr, Iraq (Mirti et al., 2009, 2008); glasses from Nishapur, Iran and Ctesiphon, Iraq (Henderson et al., 2016; Phelps, 2018) and the so-called "Low Zr Group" found at Sīraf, Iran (Swan et al., 2017).

Most of the samples in the upper part of the plot (KK-d5, KK-r4, KK-h3, KK-r1, KK-d2, KK-r3, KK-d1, KK-d4, KK-r9, KK-h2, KK-r6, KK-r5, KK-r7, KK-r8, KK-b1, KK-h4, KK-b2, KK-b3, KK-h1, KK-b4) show higher Al_2O_3 contents (between 3.57 and 4.90 wt%) compared to the Mesopotamian II group, suggesting the use of a different silica source; the closest match is with 11th-12th century glass from Ghazni, Afghanistan (Fiorentino et al., 2019) and with assemblages of glass from the Ferghana Valley and Uzbekistan (Abdurazakov, 1969; Bezborodov and Abdurazakov, 1964; Brill, 2009; Rehren et al., 2010). Last, only three samples from Kafir Kala are significantly different from the larger dataset: KK-8, KK-d9 and KK-d11. The KK-d8 and KK-d11 samples are made with natron as a flux, closely matching 1st-2nd century CE glass

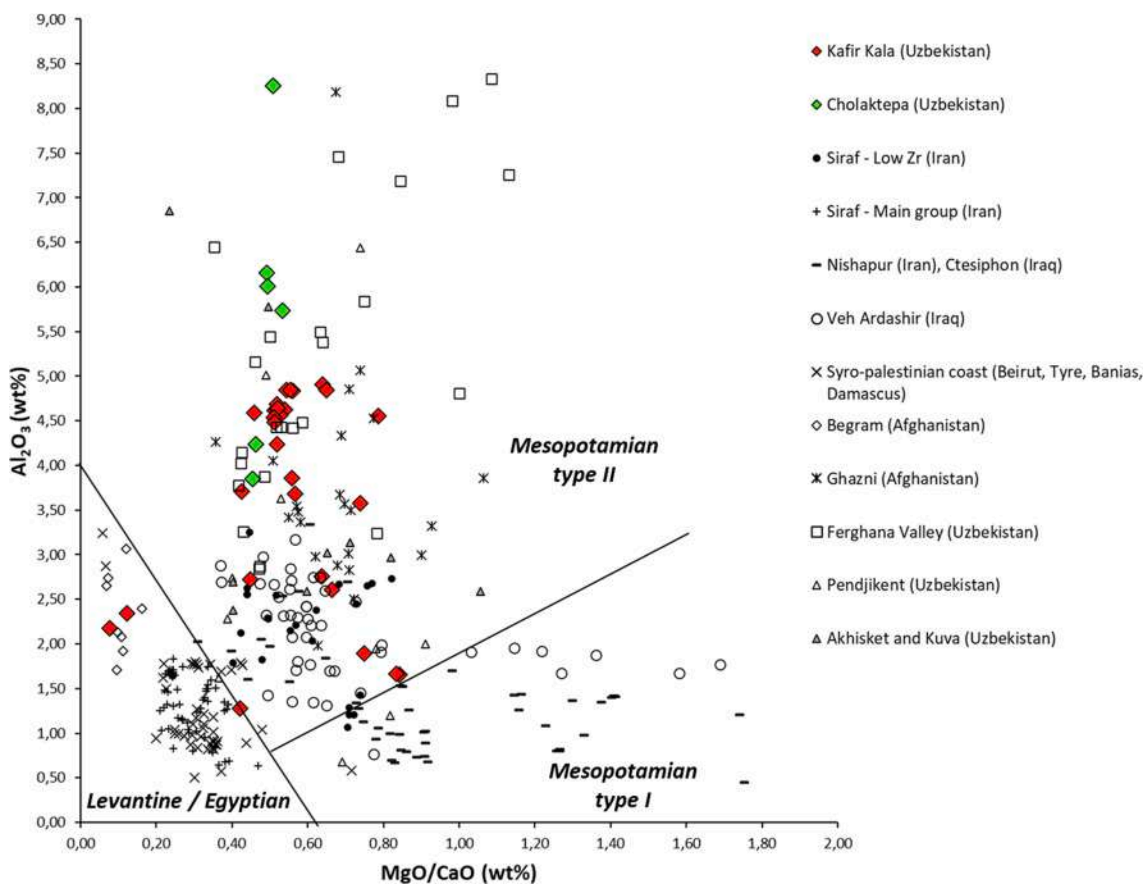


Fig. 4. Al_2O_3 versus MgO/CaO scatter plot, prepared after Phelps et al., 2018 Reference data: Abdurazakov, 1969; Bezborodov and Abdurazakov, 1964; Brill, 2009; Dussubieux and Gratuze, 2003; Fiorentino et al., 2019; Henderson et al., 2016; Mirti et al., 2009; Phelps, 2018; Rehren et al., 2010; Swan et al., 2017.

from Begram, Afghanistan, made by using natron as fluxing agent (Dussubieux and Gratuze, 2003). The KK-d9 sample (K_2O = 2.05 wt%; MgO = 3.55 wt%; CaO = 8.44 wt%) shows similarities with the Eastern Mediterranean Group, including Islamic glass from Tyre, Beirut, Banias and Damascus (Freestone et al., 2002, 2000; Henderson et al., 2016).

The plot for the Cholaktepa samples shows a correspondence between SAM-W1 and SAM-W2 and the higher Al_2O_3 content samples from Kafir Kala. SAM-GD1, SAM-GD2, and SAM-GD4 samples form a separate cluster with a higher Al_2O_3 content (between 5.74 wt% and 6.16 wt%). SAM-GD3 is an outlier, with an Al_2O_3 content of 8.25 wt%.

Variation in specific trace elements provides more in-depth insights into the raw materials used in glassmaking, specifically the vitrifying agent. In accordance with recent literature, Cr, La, Zr, and Ti will be considered, as differences in these trace element concentrations may be related to the geochemistry of sand sources (Schibille, 2022); Sr will not be considered a discriminant element because it is inextricably linked to calcium and its abundance varies according to the geology of the environment in which the plants grow, as well as how and where it accumulates within the plant (Barkoudah and Henderson, 2006).

The plot Zr/Ti vs Cr/La (Fig. 5) shows a division of the analysed glass finds into three clusters. The Cholaktepa samples form Group A, which is distinguished from the others by a higher Zr / Ti ratio, ranging between 0.38 and 0.47. The second Group, labelled Group B, contains all of the analysed glass fragments from Kafir Kala, with the exception of KK-r1, KK-r2, KK-r4, KK-b5, and KK-d9, defining a third cluster, named Group C. The samples belonging to Group C differ from those of Group B for a higher Cr / La ratio, while Zr/Ti ratios are comparable; according to recent research, Cr / La ratios greater than 5 can be considered a marker for "Mesopotamian" glass, which includes assemblages of finds from Iraq and Iran (Schibille, 2022).

In the case of Group C samples, the Cr / La ratios are well above the value of 5, ranging between 10.48 and 13.90; similar ratios are found in some 9th-10th century glass samples from Ctesiphon, Iraq (Henderson et al., 2016). The glasses from Cholaktepa in Group A do not find comparison with data published in the literature; differently, the samples belonging to Group B show similarity with assemblages found at Ghazni, Afghanistan (Fiorentino et al., 2019), with Group 1 from Samarra, Iraq (Schibille et al., 2018) and with recently published data on glass assemblages from Iranian sites along the Silk Road (Schibille et al. 2022). According to current knowledge, Samarra seems to be the only site where evidence of glass production has been uncovered. Since no evidence of glass production at other Iranian sites has been found jet, it is not possible to be more specific about the place(s) from where glass was imported to Kafir Kala. The rare earth distribution patterns (Fig. 6) confirm the division of the analysed samples into three groups; in addition to showing higher chromium contents for Group C samples, the comparison of the patterns highlights very high barium contents in Cholaktepa samples.

To gain further insights on the barium contents and related implications, the element has been plotted versus aluminium (Fig. 7a), manganese (Fig. 7b) - being barium an element linked to the silicate phases or to the raw materials used as a Mn-decolourant - and versus La and other REEs of the lanthanide series, which are typically lithophilic and thus linked to the sands used (Fig. 7c, d).

The bi-plots highlight that the wall fragments SAM-W1 and SAM-W2 are the only samples from Cholaktepa showing consistency with the finds from Kafir Kala, while all the working debris from Cholaktepa have different trends. More specifically, SAM-W2 matches the higher-Al samples from Kafir Kala, while SAM-W1.

might be a mixture of glass worked at Cholaktepa and glass found at Kafir Kala.

Framed in the historical-archaeological contexts, the data allow to identify Cholaktepa as a site dedicated to glass working between the 9th and 12th century, fusing both glass with a new composition and glass from previous periods mixed with it. The sand used as a vitrifier for the working debris from Cholaktepa shows, in fact, a different geochemical signature compared to those of the glass from Kafir Kala, which are divided into two Groups B and C; the two groups, although different in terms of sands used, show affinities with assemblages from sites located in Central Asia. In contrast, the glasses from Cholaktepa were made using a sand with higher barium contents and higher Zr/Ti ratios; the only exception, the walls SAM-W1, which can be interpreted as a mix between Cholaktepa and Kafir Kala, and SAM-W2, which is consistent with glass found at Kafir Kala.

Based on currently available data, it is not possible to define more precisely the geographical area of origin of the different sands used as

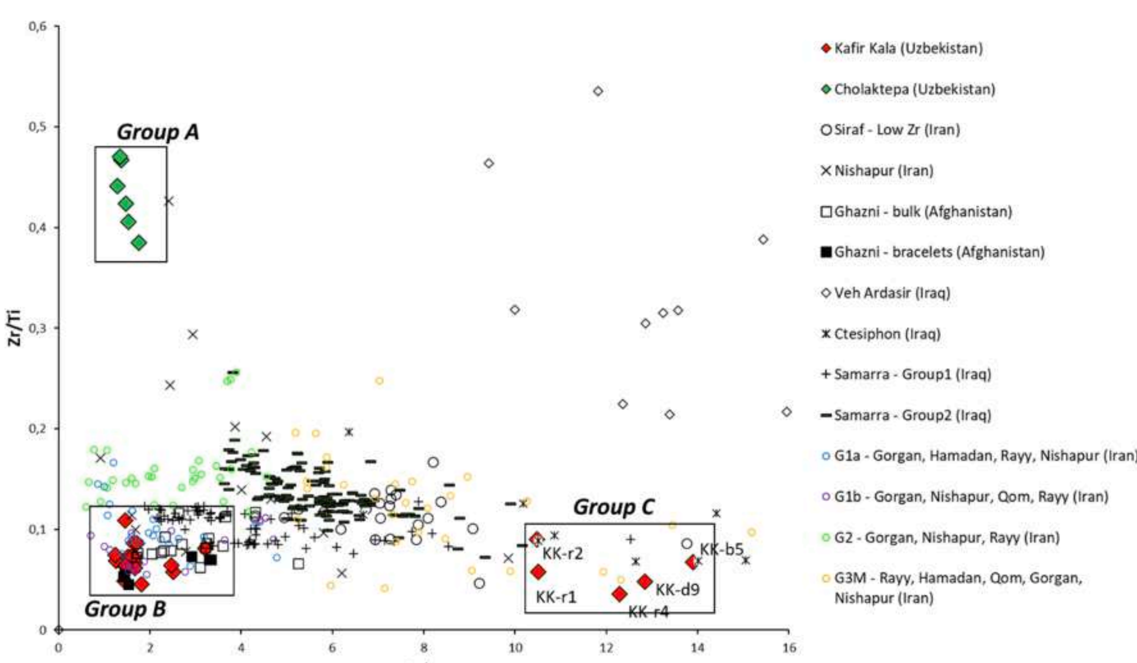


Fig. 5. Cr/La versus Zr/Ti scatter plot. Reference data: Fiorentino et al., 2019; Henderson et al., 2016; Mirti et al., 2008; Schibille et al., 2022, 2018; Swan et al., 2017.

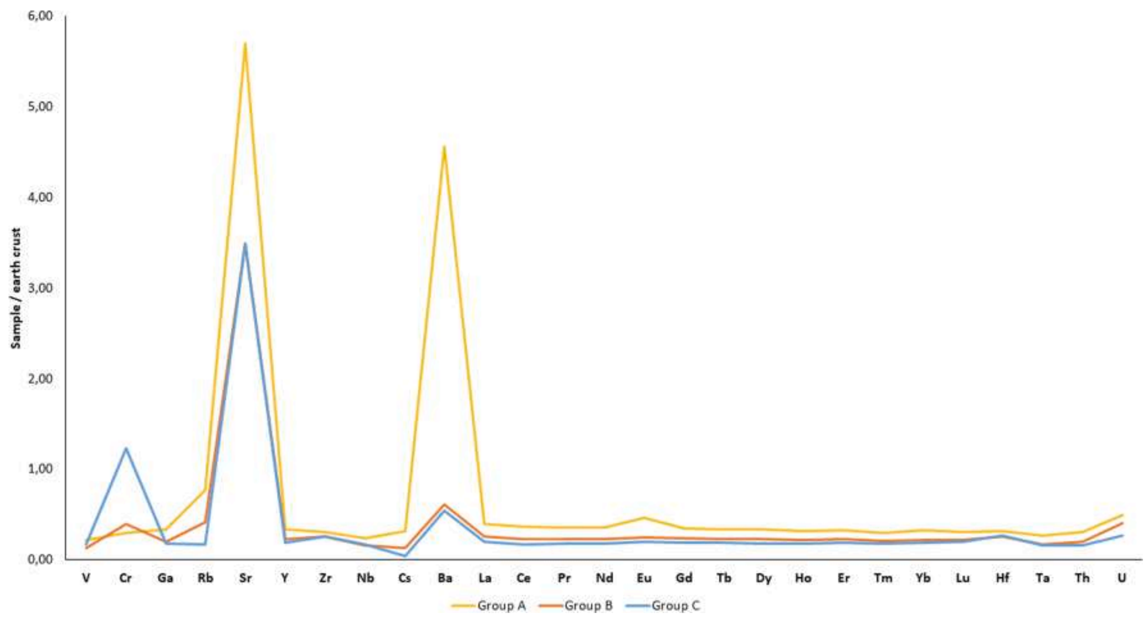


Fig. 6. Trace elements patterns obtained by LA-ICP-MS, with averages normalised to the mean values in the continental earth crust (Kamber et al., 2005).

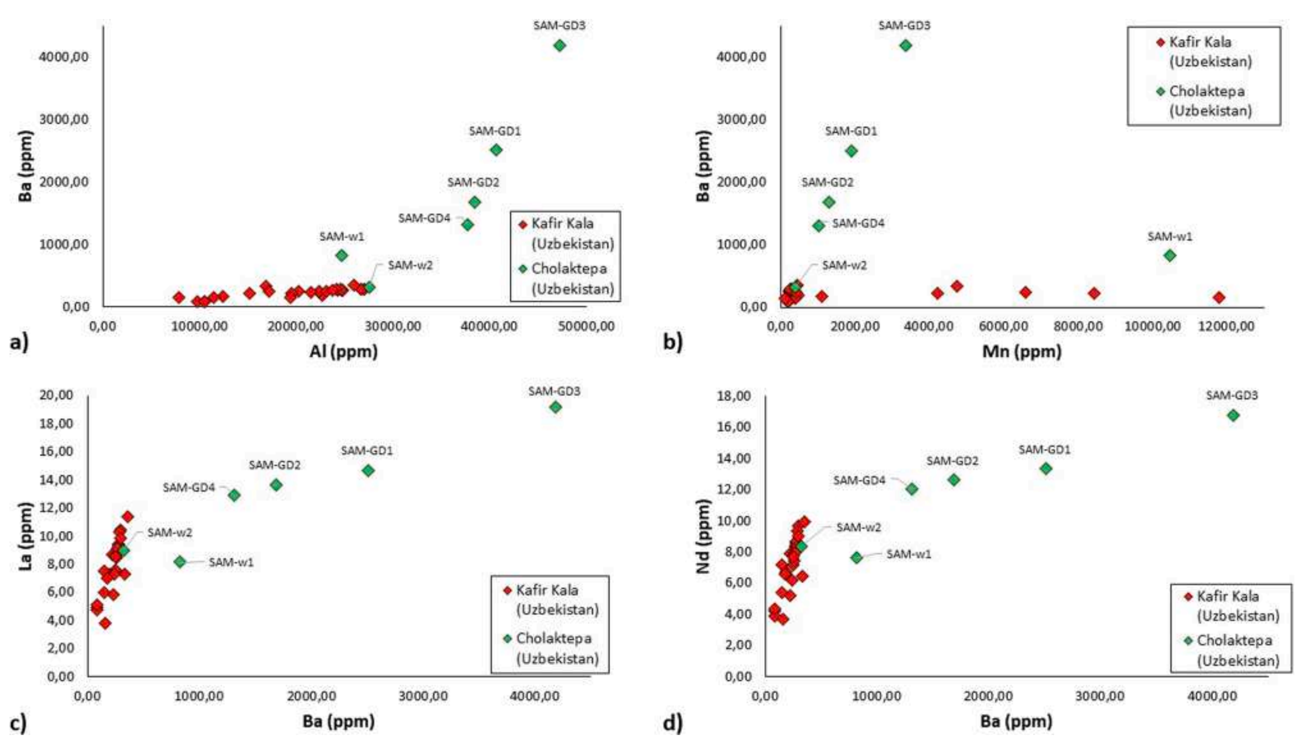


Fig. 7. Bi-plots showing correlations between a) barium and aluminium; b) barium and manganese; c) barium and lanthanium; d) barium and neodymium.

vitrifying agents. Taking the major and minor oxides into account, an intriguing comparison emerges with the 11th-12th century glass from Ferghana Valley, Uzbekistan (Fig. 4). Here, evidence of glass working has been attested in the 10th-11th century: fragments of crucibles with adhered glass and processing waste have been found, suggesting a possible local manufacture (Rehren et al., 2010). However, the lack of data on trace elements prevents a more in-depth comparison between the Ferghana Valley, Kafir Kala and Cholaktepa datasets.

4. Conclusions

The results of the chrono-typological study do not show the occurrence of distinct forms in the manufacture of everyday objects between the pre-Islamic and Islamic periods. As a result, rather than disposing of some and introducing others, there is a situation of continuity in the use of the same shapes.

From an archaeometric standpoint, relevant differences can be highlighted. Although, with the exception of kk-d8 and kk-d11, all of the samples were made with plant ash as a flux, the data show the use of different sands as a vitrifying agent.

The two Groups B and C, whose sands differ in terms of Cr/La ratios, match – although without perfectly overlapping - assemblages from other Central Asian sites. More specifically, the Group B samples are comparable with the so-called Group 1 from Samarra and with recently published assemblages from the Iranian Silk Road, while the Group C samples were made with sands with a higher chromium content, which show affinity with those used for some glasses found at Ctesiphon. Since there is no archaeological evidence of glass working and/or production at the citadel of Kafir Kala, the archaeometric data suggest an importation of the vessels from the Central Asian region.

The glass debris found at Cholaktepa define Group A, which does not find a precise comparison with the data published so far in the literature; it clearly differs from both Group B and Group C, being characterized by significantly higher Zr / Ti ratios and a higher barium content; the geochemical signature of the sands clearly shows that different sands were used as vitrifying agents. The keystone for establishing a connection between the assemblages from Kafir Kala and Cholaktepa is represented by wall fragments SAM-W1 and SAM-W2, found with working indicators. Of these two fragments, SAM-W1 may have been made by mixing glass from Cholaktepa with the same glass found at Kafir Kala, while SAM-W2 is consistent with high-Al glass from Kafir Kala. The archaeometric data therefore suggest that at Cholaktepa glass was processed of both new composition, with sands having geochemical signatures hitherto never traced in the literature (Group A), and for the remelting of glass possibly recovered from nearby Kafir Kala, which, following the Arab conquest and the fire that occurred in 712 CE, lost its role as a citadel. Based on the archaeological data, the Cholaktepa handicraft quarter would appear to have been active between the 9th and 12th centuries. Further studies on materials from both other parts of Kafir Kala, like the residential quarter (shahristan) and the outer settlement (rabad), and from other Uzbek sites are in progress to give an answer to still open questions on glass from Uzbekistan.

CRediT authorship contribution statement

Tania Chinni: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Sara Fiorentino:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Data curation. **Alberta Silvestri:** Methodology, Formal analysis, Data curation, Writing – review & editing, Supervision. **Simone Mantellini:** Writing – original draft, Writing – review & editing, Supervision. **Amriddin E. Berdimuradov:** Supervision. **Mariangela Vandini:** Writing – review & editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

The authors sincerely thank the anonymous reviewers for their comments and valuable suggestions, which have contributed to increase the quality of the manuscript.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2023.103841.

References

Abdurazakov, A.A., 1969. Medieval glasses from the Tashkent Oasis. J. Glass Stud. 31–36.

Barkoudah, Y., Henderson, J., 2006. Plant ashes from Syria and the Manufacture of Ancient Glass: Ethnographic and Scientific Aspects. J. Glass Stud. 48, 297–321.

Bass, G.F., 1984. The nature of the Serçe Limani glass. J. Glass Stud. 26, 64–68.

Benjamin, C., 2018. Empires of Ancient Eurasia. The First Silk Roads Era, 100 BCE-250 BCE. Cambridge University Press, Cambridge. Doi: 10.1017 /9781316335567.

Berdimuradov, A.E., Mukhammadiev, K.U., 2016. Arkhivnye materialy samarkandskogo gosudarstvennogo istoriko-arkhitekturnogo muzeya zapovednika i instituta arkheologii imeni Ya. Gulyamova Akademii Nauk Respubliki Uzbekistan, Arkheologia tsentralnoy azii. Arkhivnye materialy. Tom III. IICAS, Samarkand.

Bezborodov, M.A., Abdurazakov, A.A., 1964. Newly excavated glassworks in the USSR, 3rd-14th centuries A.D. J. Glass Stud. 6, 64–69.

Brill, R.H., 2009. Opening Remarks and Setting the Stage: Lecture at the 2005 Shanghai International Workshop on the Archaeology of Glass Along the Silk Road. In: Gan, F., Brill, R.H., Shouyun, T. (Eds.), Ancient Glass Research Along the Silk Road. World Scientific Publishing Co., Pte. Ltd., Singapore, pp. 109–148.

Cullen, C.L., 2009. Perfume flasks. In: Bass, G.F. (Ed.), Serçe Limani: The Glass of an Eleventh-Century Shipwreck. Texas A&M University Press, pp. 237–242.

Davidson, G.R., 1987. Glass vessels, in: Corinth. Results of Excavations Conducted by the American School of Classical Studies at Athens. The Minor Objects Vol. XII.

de la Vaissière, É., 2005. Sogdian Traders. Handbook of Oriental Studies. Section Eight. Central Asia, Brill, Leiden - Boston.

di Cugno, S., Mantellini, S., Berdimuradov, A., 2013. Traditional Techniques, Resources Exploitation and Archaeological Record: an Ethnographical Study from the Oasis of Samarkand (Uzbekistan). In: Lugli, F., Stoppiello, A.A., Biagetti, S. (Eds.), Ethnoarchaeology: Current Research and Field Methods. Conference Proceedings, Rome, Italy, 13th-14th Bar International Series 2472 May 2010, Archaeopress, Oxford, pp. 99-106.

O. Dussart, 1998. Le verre en Jordanie et en Syrie du Sud 1998 Institut francais d'archeologie du Proche-Orient Beyrouth (Liban).

Dussubieux, L., Gratuze, B., 2003. Origine et diffusion du verre dans le monde indien et en Asie du Sod-Est: l'importance du dosage des élémentes-traces. ArchéoSciences. Rev. d'Archéométrie 27, 67–73.

Fiorentino, S., Venezia, B., Schibille, N., Vandini, M., 2019. Streams across the Silk Roads? The case of Islamic glass from Ghazni. J. Archaeol. Sci. Reports 25, 153–170. https://doi.org/10.1016/j.jasrep.2019.04.002.

Fiorentino, S., Chinni, T., Galusková, D., Mantellini, S., Silvestri, A., Berdimuradov, A.E., Vandini, M., 2021. On the Surface and Beyond. Degradation Morphologies Affecting Plant Ash-Based Archaeological Glass from Kafir Kala (Samarkand, Uzbekistan). Minerals 11, 1364. https://doi.org/10.3390/min11121364.

D. Foy Le verre d'Al-Hadir M.-O. Rousset Al -Hadir. Estude Archéologique d'un Hameau de Qinnasrin (Syrie Du Nord, VIIe-XIIe Siècles). Maison de l'Orient et de la Méditerranéen 2012 Lyon (France) 129 138.

Freestone, I., Gorin-Rosen, Y., Hughes, M., 2000. Primary glass from Israel and the production of glass in Late Antiquity and the Early Islamic period, in: Nenna, M.-D. (Ed.), La Route Du Verre. Ateliers Primaires et Secondaires Du Second Millénaire Av. J.-C. Au Moyen Age. Actes Du Colloque Organisé En 1989 Par l'Association Française Pour l'Archéologie Du Verre (AFAV). La Maison de l'Orient et de la Méditerranée, pp. 65–83.

Freestone, I., Greenwood, R., Gorin-Rosen, Y., 2002. Byzantine and Early Islamic Glassmaking in the Eastern Mediterrean: Production and Distribution of Primary Glass, in: Kordas, G. (Ed.), Hyalos-Vitrum-Glass. History, Technology and Conservation of Glass and Vitreous Materials in the Hellenistic World, 1st International Conference. Rhodes, Greece, 1-4 April 2001. Glasnet, Athens, pp. 167–174.

Freestone, I., 2006. Glass production in Late Antiquity and the Early Islamic period: a geochemical perspective, in: Maggetti, M., Messiga, B. (Eds.), Geomaterials in Cultural Heritage. Geological Society of London Special Publication 257, pp. 210–16. Doi: 10.1144/GSL.SP.2006.257.01.16.

Gariboldi, A., Mantellini, S., Berdimuradov, A.E., 2018. Numismatic finds from Kafir Kala as evidence of the Islamic transition in Samarkand, in: Callegher, B., Rambach, A.D. (Eds.), 5th Simone Assemani Symposium on Islamic Coins. Rome, 29-30 September 2017 (Pp. 97–126). EUT Edizioni Università di Trieste, Trieste.

Gorin-Rosen, Y., 2010. The Islamic glass vessels. In: Gutfeld, O. (Ed.), Ramla. Final Report on the Excavations North of the White Mosque. Ahva Press, Jerusalem, pp. 213–264.

Grenet, F., de La Vaissière, É., 2022. The last days of Panjikent. Silk Road Art Archaeol. 8, 155–196.

Grigorev, G.V., 1940. Poseleniya drevnego Sogda. Po dannym issledovankiya Samarkandskogo rayona). Kratk. Soobsheniya VI, 24–34.

Hadad, S., 2005. Islamic glass vessels from the Hebrew University: excavations at Bet Shean. Excavations at Bet Shean, vol. 2. Qedem Reports, 8. The Hebrew University Of Jerusalem. Institute of Archaeology, Jerusalem (Israel).

Henderson, J., Chenery, S., Faber, E., Kröger, J., 2016. The use of electron probe microanalysis and laser ablation-inductively coupled plasma-mass spectrometry for the investigation of 8th–14th century plant ash glasses from the Middle East. Microchem. J. 128, 134–152.

Israeli, Y., 2008. The glass vessels, in: Patrich, J., Shaneb, M.A., Israeli, Y., Johnson, B.L. (Eds.), Archaeological excavations at Caesarea Maritima: areas CC, KK and NN, final reports. Volume 1, The objects. Israel Exploration Society, Jerusalem, pp. 369–418.

Jennings, S., 2006. Vessel glass from Beirut Bey 006, 007 and 045. Archaeological Studies, Berytus.

Kamber, B.S., Greig, A., Collerson, K.D., 2005. A new estimate for the composition of weathered young upper continental crust from alluvial sediments, Queensland. Australia. Geochim. Cosmochim. Acta 69, 1041–1058. https://doi.org/10.1016/j.gca.2004.08.020.

Longerich, H.P., Jackson, S.E., Gunther, D., 1996. Inter-laboratory note. Laser ablation inductively coupled plasma mass spectrometric transient signal data acquisition and analyte concentration calculation. J. Anal. At. Spectrom. 11, 899–904.

Mantellini, S., Berdimurodov, A., forthcoming. The Archaeological Map of the Middle Zeravshan Valley. The Southern Sector. Volume I: Samarkand City. Fondazione Bologna University Press, Bologna.
Mantellini, S., Berdimuradov, A.E., 2005. Archaeological explorations in the sogdian fortress of Kafir Kala (Samarkand region, Republic of Uzbekistan) 11(1–2). Anc. Civilizations from Scythia to Sib. 11, 1–2.
Mantellini, S., di Cugno, S., Dimartino, R., Berdimuradov, A.E., 2016. Change and Continuity in the Samarkand Oasis: Evidence for the Islamic Conquest from the Citadel of Kafir Kala. J. Inn. Asian Art Archaeol. 7, 227–253.
Matthews, S.D., Lledó, B., 2009. Handles and Handle- Like Objects, in: Bass, G.F., Lledo, B., Matthews, S., Brill, R.H. (Eds.), Serçe Limani, Vol 2: The Glass of an Eleventh-Century Shipwreck. Texas A&M University Press, pp. 411–415.
Mirti, P., Pace, M., Negro Ponzi, M., Aceto, M., 2008. ICP–MS analysis of glass fragments of Parthian and Sasanian epoch from Seleucia and Veh Ardas̆īr (Central Iraq). Archaeometry 50, 429–450. https://doi.org/10.1111/j.1475-4754.2007.00344.x.
Mirti, P., Pace, M., Malandrino, M., Ponzi, M.N., 2009. Sasanian glass from Veh Ardasir: new evidences by ICP-MS analysis. J. Archaeol. Sci. 36, 1061–1069. https://doi.org/10.1016/j.jas.2008.12.008.
Ouahnouna, B., 2018. RAMLA, train station: glass finds. Hadashot Arkheologigot, Excavations and Surveys in Israel. 1–16.
Ouahnouna, B., 2020. Glass Vessels from the Roman, Byzantine and Abbasid Periods at the French Hospital Compound, Yafo (Jaffa). 'Atiqot 100, 211–220.
Phelps, M., 2018. Glass supply and trade in early Islamic Ramla: an investigation of the plant ash glass. In: Rosenow, D., Phelps, M., Meek, A., Freestone, I. (Eds.), Things That Travelled: Mediterranean Glass in the First Millennium CE. UCL Press, London, pp. 236–282.
Phelps, M., Simpson, S.J., Freestone, I.C., 2018. The early Islamic glass from Ṣīr Banī Yās, UAE, in: Proceedings of the Seminar for Arabian Studies, Papers from the Fifty-First Meeting of the Seminar for Arabian Studies (British Museum, London, 4th to 6th August 2017). Archaeopress, London (UK), pp. 249–267.
Pollak, R., 2007. Excavation in Marcus Street, Ramla: The Glass Vessels, in: Contract Archaeology Reports (Reports and Studies of the Recanati Institute for Maritime Studies Excavations, University of Haifa). Haifa, pp. 100–133.
Rehren, T., Osòrio, A., Abdulhamid, A., 2010. Some notes on Early Islamic glass in Eastern Uzbekistan. In: Zorn, B., Hilgner, A. (Eds.), Glass Along the Silk RoAd From 200 BC to AD 1000 International Conference Within the Scope of the 'Sino-German Project on Cultural Heritage Preservation' of the RGZM and the Shaanxi Provincial Institute of Archaeology - December 11–12 2008. Schnell & Steiner, Meinz, pp. 93–103.
Schibille, N., 2022. Islamic Glass in the Making: Chronological and Geographical Dimensions. Leuven University Press, Leuven. https://doi.org/10.11116/9789461664419.
Schibille, N., Meek, A., Wypyski, M.T., Kröger, J., Rosser-Owen, M., Haddon, R.W., 2018. The glass walls of Samarra (Iraq): Ninth-century Abbasid glass production and imports. PLoS One 13, 5–7. https://doi.org/10.1371/journal.pone.0201749.
Schibille, N., Lankton, J.W., Gratuze, B., 2022. Compositions of early Islamic glass along the Iranian Silk Road. Geochemistry 82, 125903. https://doi.org/10.1016/j.chemer.2022.125903.
Simpson, J., 2014. Sasanian glass: an overview. In: Keller, D., Price, J., Jackson, C. (Eds.), Neighbours and Successors of Rome. Oxbow Books, Oxford, pp. 200–231.
Swan, C.M., Rehren, T., Lankton, J., Gratuze, B., Brill, R.H., 2017. Compositional observations for Islamic Glass from Sīrāf, Iran, in the Corning Museum of Glass collection. J. Archaeol. Sci. Reports 16, 102–116. https://doi.org/10.1016/j.jasrep.2017.08.020.
Usami, T., Begmatov, A., Uno, T., Berdimuradov, A., Bogomolov, G., 2017. Archaeological Excavation and Documentation of Kafir Kala Fortress. Stud. Digit. Herit. 1, 785–796. https://doi.org/10.14434/sdh.v1i2.23267.
Williams, T., 2014. The Silk Roads: an ICOMOS thematic study.