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Streams across the Silk Roads? The case of Islamic glass from Ghazni

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ABSTRACT

This paper presents data obtained by a combined chrono-typological and archaeometric study carried out on an assemblage of glassware and bracelets unearthed at the Ghaznavid Palace of Ghazni, Afghanistan. Pulsating trade and cultural centre located along the Silk Roads, the site of Ghazni has yielded evidence of an uninterrupted archaeological sequence, with settlement continuity spanning from pre-Islamic (2nd–9th/10th CE) to Islamic periods (end 10th–19th CE). Both glassware and bracelets were manufactured by using a plant ash-based glass, in line with Central Asian glassmaking technology. Furthermore, several compositional groups were identified, showing close affinities with other assemblages from Central Asia, Uzbekistan and Jordan.

1. Introduction

Established at the time of the Han dynasty of China, the Silk Roads represented a crucial connection point between the Far East and the Mediterranean basin between 130 BCE and 1453 CE. With their multifaceted land and sea routes, the Silk Roads functioned as an interconnected system not only of commercial trade, but also of cultural and technological interchange. The significance of the Silk Roads goes thus far beyond a commercial route function: in addition to the flow of goods and merchandise, the stream of people also brought transmission of knowledge, cultural values and technological expertise, reflected in material culture and in the artefacts that it encompasses (https://en.unesco.org/silkroads/about-silk-roads). In this context, glass is an ideal material to trace interregional and long-distance exchange, because glass was a 'material that travelled' (Whitehouse, 2004). This paper discusses the combined typological and archaeometric data of an assemblage of glass objects found at the Ghaznavid Palace of Ghazni, where the Italian Mission has conducted excavations since the last century (Bombaci, 1959; Scerrato, 1959; Giunta, 2009). Located about 150 km south-west of Kabul on the roads to Kandahar, the city of Ghazni (Afghanistan) was a vibrant exchange and cultural centre along the Silk Roads. The site of Ghazni and its finds reflect cultural phenomena that occurred in the region through centuries. The Italian Archaeological Mission in Afghanistan has indeed uncovered evidence of an uninterrupted archaeological sequence, with a continuous settlement spanning from the pre-Islamic (2nd–9th/10th CE) to the Islamic period (end 10th–19th CE). In virtue of this feature, Ghazni is a significant case study in which pre-Islamic and Islamic cultures overlap within the same area (http://www.ghazni.bradypus.net). Data obtained from this study will be compared with assemblages found at several sites in Central Asia, with the prime aim of highlighting analogies and differences between them and putting a particular emphasis on raw materials and compositional features. This will lead to formulate hypotheses on plausible movements of glass in the geographical area under study, defining a small step forward in the understanding of objects exchange across the routes of dialogue known as the Silk Roads, whose most enduring bequest can be marked out in the fundamental role played in connecting cultures and peoples.

2. Materials and methods

The analysed group of glass objects was selected from the assemblage recovered during the Italian Archaeological Mission in the Ghaznavid Palace of Ghazni (started in the summer of 1956 as part of the activities of the Italian Institute for the Middle and Far East) and now stored at the "Sapienza" University of Rome (Italy). Together with the two minarets still standing in the plain of the Dasht-i Manara, the Palace of Ghazni is the only architectural remain datable back to the Ghaznavid era. The Palace of Ghazni has been attributed to Mas'ud III (reg. 1099–1114) based on the discovery of some marble findings with inscriptions showing his name and/or dates that fall during his reign. However, the problematic nature of the site, its complex stratigraphy and the intricacy of the collected archaeological data in the excavation area of the building raise some doubts about the attribution of the

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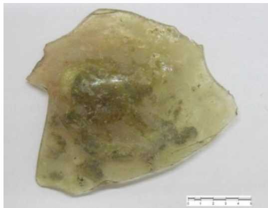
Table 1
Summary of the chrono-typological study of the selected vessels and bracelets from Ghazni.

Sample	Picture	Provenance	Typology	Size	Colour	Description	Comparisons	Dating (by form)	References
GH01		Room XVIII	Wall	L. 2.1 × 1.6 cm, T. 0.1 cm	Brown	Wall fragment with applied double-trail	1) Cup with oblique wall and flared ring-shaped base, provided with a short stem. A triple filament is applied below the rim (H. 9 cm, ø 11.4 cm). 2) Jug with cut conical body and flat base, with a long cylindrical neck and a rounded edge with a double filament applied below (H. 1.4 cm)	1) 10th–11th CE; 2) 12th CE	1) Corning Museum of Glass inv. 79.1.270; 2) Corning Museum of Glass inv. 59.1.515
GH02		Room XVIII	Bangle	L. 2.5 × 0.5 cm, T. 0.3–0.4 cm	Black	Bangle fragment			
GH03		Room XVIII	Base	H. 2.2, Ø 1.5 cm	Blue	Fragment of a miniaturistic container, with thick base, oblique and deformed wall. An applied filament is revisable as decorative pattern	Precise comparisons were not found. It certainly is a miniaturistic form, presumably a vial with a flat, thick base, cut and conical body, straight and thick edge (6.4 cm, Ø 2.9 cm). The vascular form and zoomorphic decoration are moulded	9th–10th CE	Carboni, 2001: 118, cat. n. 2.17b (LNS 168 G)
GH04		Room XVIII	Bangle	L. a 2.6 × 0.5 cm, b 1.5 × 0.5 cm, T. 0.4 cm	Black	Two fragments of a bangle, with a short upper central fairing			
GH07		Room XVIII	Bangle	L. 3.7–0.5 cm, T. 0.4 cm	Black	Fragment of a bangle with a slight upper central fairing		9th–10th CE	Bivar, 2000: 349, n. F 5/86–985
GH08		Room XVIII	Handle	H. 3.2 cm, T. 0.9 cm	Light green	Fragment of a slightly curved tubular handle	Fragment of tubular handle, probably ascribable to a pitcher with piriform body		

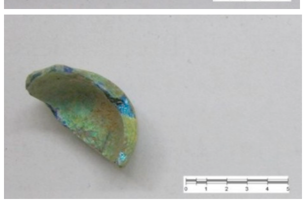
(*continued on next page*)

Table 1 (*continued*)

Sample	Picture	Provenance	Typology	Size	Colour	Description	Comparisons	Dating (by form)	References
GH09		Room XVIII	Base	L. 6.7 × 5.7 cm, T. 0.2–0.7 cm	Colourless	Base fragment with slightly accentuated umbo. A slight depression is observed on the lower surface, near the center, probably linked to signs of processing (prop?)	No relevant comparisons were found. 1) Cup with oblique wall, straight edge and slightly humbed base. Colourless, with a slight yellowish-brownish hue (H.6.6 cm, base Ø 4 cm). 2) Jug with flared cylindrical body. Lightly umbonate base, oblique shoulder, short flared collar, wavy rim. L-shaped handle with rests. Brownish brown and honeycomb printed decoration (H.16.2 cm, Ø 11.1 cm).	1) 10th CE; 2) 12th–14th CE	1) Metropolitan Museum of Art inv. 48.101.281; 2) Corning Museum of Glass inv. 66.1.5
GH11		Room XVIII	Bangle	L. 3.6 × 0.5 cm, T. 0.5 cm	Black	Bangle fragment			
GH13		Room XVIII	Handle	H. 4.6 cm, T. 1.6–1.2 cm	Light green	Fragment of a slightly curved. The piece has two linear depressions, separated by a short swelling	No relevant comparisons were found. Pitcher with piriform body, ringed foot and presumably slightly humbed base. The hem is extruded and flared. Loop with slight swelling near the rim.	12th CE	Fukai, 1977: 64
GH14		Room XVIII	Rim	H. 0.7 cm, Ø 1.5–2.1 cm,T. 0.2 cm	Light green	Fragments of estroflexed hem, short neck and shoulder fragment.	1) Jar with extruded edge, short neck, shoulder with an almost horizontal profile, flared wall and umbonate base (H: 7.9 cm, Ø 9.9 cm). 2) Small jar. Thick, irregular base, shoulder with slight depression near the neck, short, thick and outfolded rim (8.5–9 cm, Ø 6.2 cm, Ø 5.5 cm).	1) 11th–12th CE; 2) 10th CE	1) Metropolitan Museum of Art inv. 30.40.1; 2) Kröger, 1995: 63, n. 59 (MMA inv. 38.40.196)
GH16		Room XVIII	Bangle	L. 4.6 × 0.6 cm, T. 0.4 cm	Black	Fragment of deformed bangle			

(*continued on next page*)

Table 1 (*continued*)

Sample	Picture	Provenance	Typology	Size	Colour	Description	Comparisons	Dating (by form)	References
GH17		Room XVIII	Wall	L. 3.9 × 3.8 cm, T. 0.5–0.2 cm	Aqua	Fragment of wall with decoration in negative (six small cases and one inscribed inside). The presence ofimprinted lines also suggests a register decoration	1) Flask with cylindrical body, slightly moistened base, depression near the shoulder, slightly flared cylindrical neck, extruded rim. Yellowish green glass. The decoration is made in negative mould, with a sequence of dotted routes. In the middle of the base, concentric circles are observed (h 9.9 cm, base Ø 5.3 cm). 2) Small jug with cylindrical body. Flat base, short horizontal shoulder, long neck slightly flared near the rounded edge. Tubular handle and short rest. Decorated in mould with drop motifs on the body and dotted rosettes on the base (H. 10.5 cm, Ø 4.5 cm).	1) 12th CE 2) 11th–12th CE	1) Svobodovà, 2014: pl. 29, n 9; 2) Carboni and Whitehouse, 2001: 252, cat. n. 3.43b (LNS 160 G)
GH18		Room XVIII	Rim	H. 2 cm, rim Ø 2 cm, T. 0.4 cm	Turquoise	Fragment of straight edge and vertical wall. Probably ascribable to a plate or a cup	1) Cup with slightly tapered wall near the straight edge. Flat base with light central humidation near the shore mark (6.5 cm, Ø 30 cm); 2) Fragment of slightly flared wall plate, straight edge and flat base, perhaps originally provided with foot (h.1 cm, Ø 28 cm); 3) Cup with vertical wall. Flat base, central thickening, straight rim(3.2 cm).	1–2) 9th–10th CE; 3) 10th–11th CE	1) Kröger, 1995: 43, n. 6 (Tehran, Iran Bastan Museum) 2) Kröger, 1995: 117–119, n. 164 (MMA inv. 40.170.131); 3) British Museum inv. 1951,0507.7
GH20		Room XVIII	Base	H. 0.6 cm, L. 3 cm, T. 0.4 cm	Colourless	Base fragment with folded ring-shaped foot	Base fragment of cup or bottle, with ring-shaped foot and a slight central umbonation.	9th–10th CE	Bivar, 2000: 346, n. F1/ 86–988
GH21		Room XVIII	Base	H. 1.2 cm, Ø 1.6 cm, T. 0.5 cm	Blue	Flat, thick base fragment and small fragment of a vertical wall of a miniature container, presumably with a cylindrical body and mould-made	1) Flask with cylindrical body with flat and thick base and flared wall (H.6 cm, base Ø 1.7 cm). The comparison, however, shows a an engraved decoration with teardrop motifs on the body and circular elements near the shoulder. 2) Vial with cylindrical body. Flat base, shoulder with an almost horizontal profile, cylindrical neck, straight rim (H 5.2 cm, Ø 1.6 cm). The comparison presents a decoration with light horizontal cuts (wheel-cut). 3) Flask with flared cylindrical body. Flat, thick base, oblique shoulder, flared collar, straight and thick rim. Dark blue in colour (7.8 cm, Ø 1.8 cm).	1–2) 9th–10th CE; 3) 11th–12th CE	1) Bivar, 2000: 343, F 3/ 72–189; 2) Kröger, 1995: 150, n. 201 (Tehran, Iran Bastan Museum); 3) Kordmahini, 1994: 88, n. 58

(*continued on next page*)

Table 1 (*continued*)

Sample	Picture	Provenance	Typology	Size	Colour	Description	Comparisons	Dating (by form)	References
GH22		Room XVIII	Bangle	L. 3.5 × 0.7 cm, T. 05 cm	Black	Bangle fragment			
GH23		Room XVIII	Handle	L. 1.9 × 1 cm, T. 0.4 cm	Aqua with yellow trails	Handle fragment with a three filaments applied decoration	No precise comparison was found. It could be a fragment of a handle (due to its defined and flat shape), but it was not possible to find analogous decorative patterns on other glass vessels's handles.		
GH24		Mosque XIII	Foot	H. 1.5 cm, Ø 7 cm, L. 3.9 × 1.4 cxm, T. 0.5–0.3 cm	Green	Two merging fragments with a flared foot and a residual part of the stem attachment. Perhaps glass base on high stem (goblet)	1) Goblet with flared foot and long tubular stem, tapered near the cup. A bearing of vitreous material is recorded between the stem and the base (7.7 cm, Ø 4.8 cm). 2) Goblet with disc foot, with a sloping profile, spherical bearing at the point of juncture to the cup with straight edge.	9th–10th CE	1) Metropolitan Museum of Art inv. 40.170.451; 2) Lamm, 1929: Tafel 2, n. 30
GH25		Mosque XIII	Base	H. 1.6 cm, Ø sup. 2 cm, T. 0.4 cm	Colourless	Fragment of a small container, with an apodic and thick base	1) Measuring apode bottle, with long cylindrical body slightly flared near the rim, thick and outfolded. 2) Apode bottle in translucent green glass (H 11.7 cm, Ø 1 cm). 3) Inner inkwell compartment, slightly flared and cylindrical. Inkwell with flat base, flared wall, rounded shoulder, flat edge and three handles (H.4 cm, Ø 4.4 cm). 4) Inner inkwell compartment, slightly flared and cylindrical. The compartment is attached to the flat edge of the inkwell (H. 3.8 cm, L. 7.2 cm). 5) Internal inkwell compartment. Envelope with globular body inserted in a spherical coating of plaster (Ø 9.6 cm). 6) Internal inkwell compartment. Inkwell with cylindrical body, tapered near the flat base. Thick rim and three loops. 7) Inner inkwell compartment. Inkwell with cylindrical body, tapered near the flat base. Thick rim and six loops (H 7.2 cm, Ø 7.3 cm).	1)9th–10th CE; 2) 8th–9th CE; 3–5) 10th CE; 6) 10th CE; 7) 9th–10th CE	1) British Museum inv. OA + 0.8831; 2) Kordmahini, 1994: 44, Collezione Bazargan inv. 21914; 3) Tehran, Iran Bastan Museum inv. 20381; 4) Metropolitan Museum of Art inv. 48.101.275; 5) Kröger, 1995: 178, n. 231; 6) Metropolitan Museum of Art inv. 69.148; 7) Carboni, 2001: 142, cat. n. 33b (LNS 89 G)

(*continued on next page*)

Table 1 (*continued*)

Sample	Picture	Provenance	Typology	Size	Colour	Description	Comparisons	Dating (by form)	References
GH26		Room XXX	Handle	L. 1.6–1.4 cm, T. 0.3–0.7 cm	Light green	Fragment of handle or decorative element. The presence of two swollen elements of different dimensions divided by a depressed linear element is recorded. On the opposite surface there is a small element in relief, similar to a small boss, but probably do not belonging to the decorative motifs	No precise comparisons were found. If it were a decorative element: 1) Bottle with a globular body (H 8.9 cm, Ø 7.8 cm) and embossed decoration with wavy elements at the junction between the shoulder and the body; 2) Anthropomorphous Rython (H.19 cm) provided with several applied wavy elements. 3) Bottle with piriform body with high umbo base and swollen neck tapered near the straight edge. Two short and cirrular handles inserted into a dentellinated decoration system.	1) 8th CE; 2) 7th–8th CE; 3) 12th CE	1) Carboni and Whitehouse, 2001: 115 n. 34; 2) Carboni and Whitehouse, 2001: 117, 35; Carboni, 2001: 183, cat. n. 46.c (LNS 346G)
GH27		Room XXX	Handle	H. 2.6 cm, T. 0.6 × 1.3 cm	Light green	Handle fragment, tapered, with a swollen element near one of the ends	No relevant comparisons were found. 1) Element of mosque lamps' decorative system (H.14 cm, Ø 9 cm). 2) Handle element. Jug with a cut conical body, wide and cylindrical neck, vertical rim. Openworked handle with different thread-like elements (17.8 cm).	1) 11th–12th CE; 2) 12th CE	1) Kordmahini, 1994: 115, inv. 21,929; 2) Corning Museum of Art inv. 59.1.515
GH28		Room XXXI	Handle	H. 7 cm, T. 0.6–1.1 cm	Light green	"C"-shaped handle fragment. Presence of a depression with following swelling near one of the two ends	No precise comparisons were found. Cup with thick ring-shaped foot, flat base, poly-lobed wall and vertical edge. Ring loop with finger rest (H 4.5 cm, Ø 8.2 cm).	9th–10th CE	British Museum inv. 1991,1010.3;
GH29		Room XXXI	Handle	H. 7 cm, T. 1 × 1.3 cm	Light green	Handle fragment. There is a slight taper near the curvature and a depression followed by swelling near the opposite end, which could suggest the presence of a finger rest	No precise comparisons were found. Similar handle elements are typical of cylindrical pitchers. Jug with a sub-globular body (H.7.7 cm, Ø 5.5) with ribbon-shaped handle.	9th–12th CE	Kordmahini, 1994: 105; inv. 22015

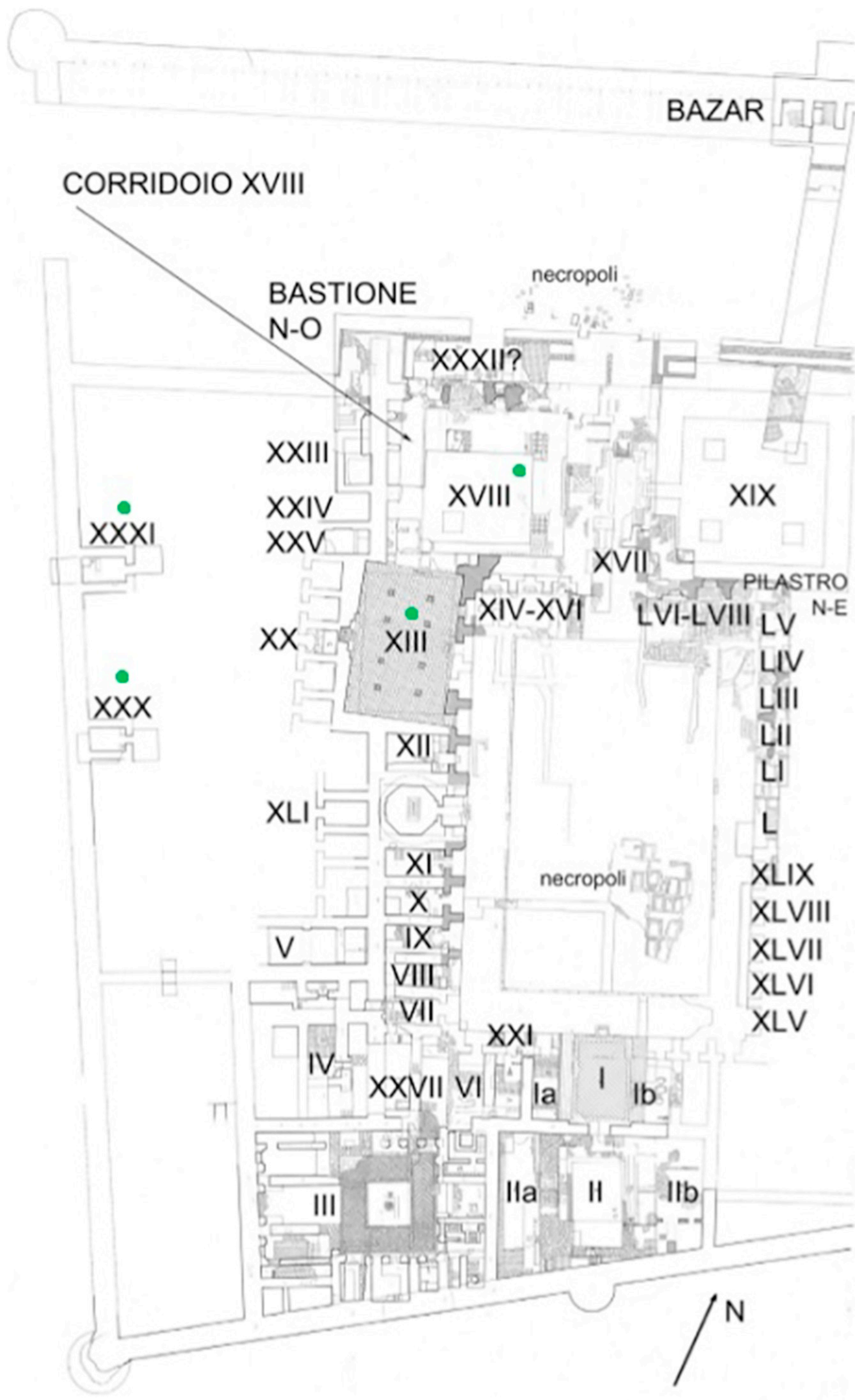


Fig. 1. Plan of the Palace with, in green, collecting points of the glass finds under study (adapted from Venezia, 2015).

foundation of the building to this ruler. After the destruction started by the Mongols and perpetuated by the occurrence of both natural disasters and political issues, the palace was progressively transformed into a cemetery area.

Materials found in the palace can be ascribed to a period between the years of the reign of Mas'ud III's father, Ibrahim b. Mas'ud I (1059–1099), and the end of the 12th century CE. From > 1200 fragments recovered, twenty-three fragments were selected for this study (Table 1). The largest concentration of glass finds was encountered in Room XVIII (16 fragments), and some finds were recovered from Rooms XXX (2 fragments), XXXI (2 fragments) and from the Mosque – Room XIII (3 fragments) (Fig. 1). Selection was made on the basis of archaeological and chrono-typological criteria, preferably choosing samples with well-documented or recognisable forms. The selection includes eight bases, six handles, three rims, and two wall fragments as well as five pieces of jewellery (Table 1). The shape of the rim, the shape of the wall and the colour of the glass suggest that GH 14 can be related to jars, with a height between 7 cm and 9 cm, while GH18 can be associated with bowls and plates with a diameter of 28 cm to 30 cm. Of the eight base fragments, GH03, GH21 and GH25 are probably related to miniature vessels. Despite the low quality and the absence of detailed comparisons, GH03 could be an example of a reworked vessel.

Table 2
EPMA data for major and minor oxides. Data are reported as wt%; nd is for not detected.

EPMA data for major and minor oxides (wt%)																						
Sample	Typology	Colour	Opacity	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	FeO	CoO	CuO	As_2O_3	SnO_2	Sb_2O_3	PbO	Total
GH01	wall	brown	transparent	19.06	2.21	3.00	70.28	0.23	0.18	1.88	0.97	2.46	0.15	0.12	0.84	nd	0.02	0.02	0.02	0.02	0.02	101.49
GH02	bracelet	black	opaque	18.33	4.66	8.18	53.34	0.70	0.80	0.94	5.06	6.92	0.54	0.10	2.23	0.01	0.02	nd	nd	0.02	0.03	101.88
GH03	distort bottom	light green	transparent	20.11	4.53	3.32	61.23	0.43	0.38	0.97	2.81	4.89	0.18	0.75	1.23	0.01	1.27	0.02	0.02	0.02	0.02	102.18
GH04	bracelet	black	opaque	18.55	5.06	4.53	58.70	0.52	0.42	1.21	6.19	6.54	0.21	0.08	0.94	0.01	0.01	0.01	0.01	0.05	0.04	103.07
GH07	bracelet	black	opaque	19.99	4.73	2.88	62.07	0.41	0.49	1.34	2.70	6.98	0.14	0.14	0.72	0.00	0.11	0.01	0.01	0.01	0.01	102.76
GH08	handle	light green	transparent	18.21	6.04	3.50	59.95	0.42	0.27	0.88	2.79	8.48	0.18	0.14	1.32	nd	0.06	0.02	0.02	0.01	0.02	102.30
GH09	base	colourless	transparent	20.38	2.94	3.86	66.45	0.17	0.14	1.58	0.93	2.76	0.13	1.35	0.99	0.01	0.01	0.01	nd	0.01	0.03	101.76
GH11	bracelet	black	opaque	20.08	4.01	3.48	61.75	0.50	0.52	1.39	2.60	6.96	0.18	0.19	1.22	0.01	0.02	nd	0.01	0.02	0.01	102.97
GH13	handle	light green	transparent	18.59	4.56	3.57	61.39	0.46	0.24	0.96	3.55	6.54	0.18	0.72	1.26	0.01	0.02	nd	0.01	0.01	0.05	102.12
GH14	rim	light green	transparent	20.27	3.90	4.85	62.07	0.32	0.20	1.27	2.23	5.50	0.25	0.40	1.64	0.01	0.03	0.01	0.02	0.01	0.05	103.02
GH16	bracelet	black	opaque	19.20	3.95	3.54	62.57	0.48	0.57	1.42	2.56	6.93	0.17	0.19	1.23	0.01	0.03	0.01	0.01	0.02	0.05	102.92
GH17	base	aqua	transparent	13.97	4.40	1.98	66.05	0.63	0.21	0.88	5.64	7.02	0.11	0.09	0.70	nd	0.01	0.01	0.01	0.03	0.02	101.78
GH18	rim	turquoise	transparent	16.78	3.27	3.42	63.40	0.36	0.25	1.10	3.84	5.94	0.11	0.20	0.79	nd	2.20	0.02	0.01	0.05	0.06	101.80
GH20	base	colourless	transparent	19.28	4.37	2.98	62.63	0.43	0.36	0.86	2.61	7.04	0.16	1.00	0.82	0.01	0.02	0.01	0.01	0.01	0.03	102.63
GH21	base	blue	translucent	16.40	3.98	3.37	62.40	0.41	0.27	0.84	4.18	6.86	0.12	0.66	0.84	0.02	1.13	0.03	0.01	0.04	0.07	101.62
GH22	bracelet	black	opaque	17.76	4.22	5.07	59.12	0.55	0.54	1.32	7.12	5.71	0.18	0.06	1.07	0.01	0.01	0.01	0.01	0.04	nd	102.80
GH23	handle	aqua with yellow trails	transparent/opaque	13.82	3.88	4.34	51.54	0.52	0.12	0.80	5.40	5.63	0.21	1.20	1.32	0.01	0.04	nd	0.79	0.01	9.72	99.35
GH24	foot	green	transparent	12.36	3.16	4.27	65.00	0.46	0.36	0.32	3.11	8.88	0.18	0.06	1.16	nd	1.51	0.02	0.01	0.05	0.10	101.01
GH25	base	colourless	transparent	16.46	4.25	4.05	60.87	0.59	0.36	0.48	4.37	8.37	0.07	0.96	0.50	0.01	0.03	0.02	0.01	0.03	0.03	101.46
GH26	handle	light green	transparent	17.65	4.26	3.01	63.82	0.44	0.23	1.01	3.08	6.02	0.14	0.75	1.12	nd	0.03	0.01	0.01	0.01	0.03	101.64
GH27	handle	light green	transparent	18.56	4.35	3.67	62.31	0.44	0.24	1.04	3.30	6.36	0.17	0.93	1.22	0.01	0.02	nd	0.03	0.01	0.06	102.72
GH28	handle	light green	transparent	17.84	4.42	2.83	63.23	0.50	0.26	1.03	4.13	6.22	0.14	0.39	1.03	0.01	0.04	0.01	0.01	0.02	0.03	102.13
GH29	handle	light green	transparent	19.24	4.41	2.51	61.10	0.67	0.29	0.97	4.46	6.11	0.14	0.87	0.94	0.01	0.26	nd	0.00	0.04	0.03	102.04

Table 3
LA-ICP-MS data for major and minor oxides (%) and for trace elements (ppm); nd is for not detected.

LA-ICP-MS data for major and minor oxides (wt%) and for trace elements (ppm)

Sample	Typology	Colour	Opacity	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CuO	SnO_2	PbO
GH01	wall	brown	transparent	20.1	1.48	2.71	69.5	0.18	1.36	0.95	2.45	0.14	0.10	0.92	0.00	nd	nd
GH02	bracelet	black	opaque	17.6	3.96	8.59	53.8	0.56	0.75	5.03	6.68	0.48	0.09	2.24	0.01	nd	nd
GH03	distort bottom	light green	transparent	19.9	3.36	3.26	61.4	0.35	0.75	2.95	4.76	0.16	0.63	1.21	1.08	0.01	nd
GH04	bracelet	black	opaque	17.6	4.02	4.51	58.8	0.38	0.99	6.33	6.00	0.18	0.06	0.87	0.00	nd	nd
GH07	bracelet	black	opaque	19.6	3.44	2.78	62.3	0.30	1.01	2.79	6.46	0.12	0.11	0.73	0.12	nd	nd
GH08	handle	light green	transparent	17.7	4.62	3.76	60.4	0.31	0.80	2.91	7.60	0.16	0.10	1.40	0.04	nd	0.01
GH09	base	colourless	transparent	19.8	2.13	2.88	67.2	0.17	1.24	0.86	3.01	0.12	1.27	1.08	0.00	nd	nd
GH11	bracelet	black	opaque	19.1	2.96	3.41	62.1	0.36	1.06	2.65	6.60	0.16	0.15	1.25	0.03	nd	nd
GH13	handle	light green	transparent	17.8	3.53	3.76	61.6	0.35	0.76	3.59	6.33	0.17	0.58	1.26	0.03	nd	0.04
GH14	rim	light green	transparent	19.2	2.81	5.22	61.8	0.26	0.98	2.29	5.06	0.22	0.32	1.64	0.03	nd	0.02
GH16	bracelet	black	opaque	19.1	2.96	3.42	62.0	0.36	1.06	2.66	6.61	0.16	0.15	1.25	0.03	nd	nd
GH17	base	aqua	transparent	13.6	3.80	1.98	65.8	0.49	0.67	5.85	6.77	0.09	0.07	0.75	0.00	nd	nd
GH18	rim	turquoise	transparent	16.7	2.58	3.56	63.1	0.31	0.83	3.91	5.66	0.10	0.16	0.83	2.06	0.01	0.03
GH20	base	colourless	transparent	18.7	3.49	3.14	62.0	0.37	0.63	2.61	7.05	0.14	0.83	0.87	0.02	nd	nd
GH21	base	blue	translucent	16.2	3.28	3.45	62.3	0.36	0.62	4.25	6.57	0.11	0.56	0.95	1.10	0.01	0.03
GH22	bracelet	black	opaque	17.3	3.59	5.19	58.2	0.42	1.03	7.34	5.48	0.17	0.06	1.00	0.00	nd	nd
GH23	handle	**aqua** with yellow trails	transparent	16.0	4.08	5.23	57.7	0.57	0.83	6.27	6.39	0.23	0.87	1.56	0.01	nd	0.01
		aqua with **yellow trails**	opaque	13.8	3.42	4.56	51.1	0.54	0.72	5.47	5.39	0.20	1.04	1.43	0.03	1.24	10.8
GH24	foot	green	transparent	12.2	2.88	4.44	64.6	0.38	0.31	3.21	8.74	0.16	0.05	1.27	1.51	nd	0.04
GH25	base	colourless	transparent	15.9	3.65	4.12	61.1	0.46	0.41	4.61	8.12	0.07	0.75	0.54	0.04	nd	0.01
GH26	handle	light green	transparent	17.9	3.41	3.37	62.5	0.33	0.77	3.10	6.27	0.15	0.66	1.22	0.05	nd	0.03
GH27	handle	light green	transparent	17.8	3.44	3.67	62.0	0.38	0.76	3.30	6.25	0.02	0.80	1.25	0.03	nd	0.03
GH28	handle	light green	transparent	17.6	3.51	2.97	62.7	0.40	0.83	4.11	6.02	0.14	0.37	1.11	0.02	nd	0.03
GH29	handle	light green	transparent	19.0	3.50	2.55	61.2	0.49	0.69	4.65	5.78	0.12	0.71	1.00	0.19	nd	0.01

Sample	Typology	Colour	Opacity	Li	B	Ti	V	Cr	Co	Ni	Zn	Ga	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd	Sb	Cs	Ba	La
GH01	wall	brown	transparent	25.6	415	815	10.5	26.6	2.25	13.7	32.0	3.89	1.53	9.20	227	5.74	91.9	3.26	0.21	0.07	0.04	0.17	0.30	78.0	7.28
GH02	bracelet	black	opaque	35.8	195	2904	39.2	47.3	5.05	5.78	43.4	14.0	2.38	69.79	318	20.6	161	8.66	0.62	0.13	0.04	0.00	2.09	345	32.7
GH03	distort bottom	light green	transparent	28.5	230	960	17.2	39.2	3.57	25.2	70.2	4.83	5.39	20.99	421	6.97	112	3.46	0.92	0.64	0.06	12.6	0.57	163	9.09
GH04	bracelet	black	opaque	21.3	191	1058	14.9	18.9	2.21	8.98	20.1	6.17	0.99	55.23	365	8.46	56.6	3.33	0.52	0.13	0.04	0.31	0.62	825	13.3
GH07	bracelet	black	opaque	26.6	232	698	14.6	23.3	2.39	10.0	23.0	4.22	2.09	28.94	508	5.88	51.2	2.11	0.39	0.80	0.01	2.33	nd	127	8.02
GH08	handle	light green	transparent	22.3	254	985	21.7	31.8	4.64	15.9	52.1	5.10	5.39	22.98	485	7.23	90.4	3.39	0.90	0.54	0.07	1.56	nd	222	9.68
GH09	base	colourless	transparent	29.7	426	745	12.3	20.6	2.86	21.4	56.3	4.20	6.28	8.50	363	6.88	86.8	3.23	0.44	0.09	0.09	0.46	nd	188	7.85
GH11	bracelet	black	opaque	26.6	257	932	19.2	33.5	3.10	10.3	29.4	5.09	2.75	27.99	528	7.07	65.1	2.86	0.29	1.77	0.02	1.01	nd	147	10.0
GH13	handle	light green	transparent	29.3	237	1005	18.8	33.8	4.08	16.0	43.0	5.37	7.40	30.73	470	7.55	82.4	3.24	0.78	0.38	0.05	1.66	nd	320	10.5
GH14	rim	light green	transparent	32.6	379	1338	23.4	58.2	5.21	24.5	56.7	6.38	3.65	25.32	370	8.05	89.1	4.09	0.46	0.35	0.04	1.25	nd	280	11.1
GH16	bracelet	black	opaque	26.8	257	934	19.2	33.9	3.18	11.5	29.8	5.11	2.83	28.15	530	7.14	65.7	2.88	0.30	0.44	0.02	1.07	nd	151	10.3
GH17	base	aqua	transparent	22.4	150	563	12.4	16.2	2.13	7.94	28.0	3.57	1.44	28.29	359	4.76	42.6	2.06	0.54	0.06	0.04	0.03	nd	100	7.90
GH18	rim	turquoise	transparent	27.3	104	628	16.9	20.0	4.61	25.7	67.7	4.73	67.7	27.03	350	6.88	48.5	1.90	0.30	17.60	0.04	99.0	nd	185	8.90

(*continued on next page*)

Table 3 (*continued*)

Sample	Typology	Colour	Opacity	Li	B	Ti	V	Cr	Co	Ni	Zn	Ga	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd	Sb	Cs	Ba	La
GH20	base	colourless	transparent	25.3	213	835	17.2	24.8	3.11	11.2	27.9	4.92	2.36	27.92	588	7.48	66.3	2.71	0.35	0.22	0.03	0.04	nd	132	10.1
GH21	base	blue	translucent	31.6	123	655	17.5	20.1	32.7	52.7	81.8	4.75	128	26.52	376	6.89	51.8	1.95	1.02	9.68	0.05	59.2	nd	274	8.73
GH22	bracelet	black	opaque	39.4	193	1003	14.9	19.6	2.16	4.77	22.5	6.49	0.82	82.70	300	7.40	45.9	3.31	0.80	nd	0.01	0.19	nd	1017	12.9
GH23	handle	**aqua** with yellow trails	transparent	33.0	218	1354	19.1	24.4	3.38	11.9	32.4	7.22	2.50	52.74	389	10.4	98.3	4.37	0.71	nd	0.13	0.80	0.62	876	14.4
		aqua with **yellow trails**	opaque	29.3	188	1178	17.4	24.4	3.73	20.7	33.6	6.34	89.0	47.36	343	9.51	99.4	3.98	0.78	8.40	0.15	106	0.59	754	12.6
GH24	foot	green	transparent	72.1	175	965	23.0	29.8	3.39	23.8	59.7	5.77	92.9	23.54	472	7.75	60.4	2.78	0.21	18.2	0.09	204	nd	138	9.62
GH25	base	colourless	transparent	10.6	112	407	11.8	12.8	3.12	11.1	25.0	4.68	12.1	51.20	506	7.37	31.2	1.46	1.04	nd	0.09	17.9	nd	551	7.41
GH26	handle	light green	transparent	29.5	252	905	17.7	34.3	4.53	16.2	41.7	4.83	8.06	25.82	488	7.04	75.5	2.98	0.78	0.03	0.04	2.87	nd	223	9.54
GH27	handle	light green	transparent	28.4	235	955	17.7	33.2	3.60	17.3	41.7	5.28	10.8	27.99	488	7.53	82.2	3.32	0.78	0.33	0.05	3.48	nd	263	10.2
GH28	handle	light green	transparent	26.6	208	814	16.3	26.3	3.38	13.3	36.8	4.52	4.94	26.57	384	6.76	69.8	2.62	0.92	0.34	0.04	1.08	nd	211	9.71
GH29	handle	light green	transparent	25.2	190	744	16.4	20.2	5.66	13.0	49.2	4.25	9.67	31.82	325	5.73	69.0	2.81	1.20	0.96	0.06	3.67	nd	314	8.67

Sample	Typology	Colour	Opacity	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Pt	Au	Bi	Th	U
GH01	wall	brown	transparent	14.5	1.51	5.90	1.18	0.21	1.19	0.17	0.96	0.20	0.58	0.09	0.65	0.10	2.41	0.29	0.15	nd	nd	0.03	3.45	1.25
GH02	bracelet	black	opaque	65.2	6.84	26.9	5.22	0.95	5.22	0.69	3.69	0.74	2.06	0.28	2.08	0.29	4.19	0.63	0.33	nd	nd	0.01	11.0	5.62
GH03	distort bottom	light green	transparent	17.4	1.90	7.40	1.48	0.29	1.50	0.21	1.19	0.24	0.72	0.10	0.76	0.11	2.87	0.29	0.27	nd	0.09	0.09	3.78	1.22
GH04	bracelet	black	opaque	25.4	2.70	10.4	2.03	0.52	2.12	0.27	1.44	0.31	0.82	0.12	0.81	0.12	1.56	0.23	0.19	nd	0.02	0.01	3.69	0.76
GH07	bracelet	black	opaque	16.5	1.72	6.70	1.32	0.27	1.35	0.18	1.02	0.21	0.57	0.08	0.58	0.08	1.50	0.16	0.17	nd	nd	0.14	3.07	0.61
GH08	handle	light green	transparent	18.6	2.01	7.77	1.56	0.32	1.60	0.22	1.25	0.26	0.73	0.11	0.78	0.11	2.36	0.24	0.37	nd	0.01	0.28	3.61	1.04
GH09	base	colourless	transparent	13.6	1.59	6.40	1.31	0.24	1.35	0.19	1.12	0.23	0.67	0.10	0.78	0.11	2.30	0.32	0.15	nd	nd	0.06	3.60	1.42
GH11	bracelet	black	opaque	20.3	2.13	8.21	1.65	0.34	1.66	0.22	1.22	0.25	0.70	0.10	0.72	0.10	1.82	0.22	0.17	nd	nd	0.05	3.82	0.77
GH13	handle	light green	transparent	20.2	2.18	8.57	1.68	0.38	1.76	0.24	1.29	0.27	0.75	0.11	0.76	0.11	2.21	0.24	0.26	nd	nd	0.10	3.59	0.94
GH14	rim	light green	transparent	21.0	2.26	8.84	1.73	0.40	1.82	0.25	1.35	0.28	0.82	0.12	0.86	0.13	2.31	0.30	0.23	nd	0.01	0.10	3.78	1.16
GH16	bracelet	black	opaque	20.6	2.16	8.32	1.61	0.33	1.67	0.23	1.23	0.25	0.68	0.10	0.72	0.10	1.78	0.22	0.18	nd	nd	0.07	3.86	0.77
GH17	base	aqua	transparent	16.1	1.68	6.65	1.28	0.25	1.29	0.16	0.87	0.18	0.48	0.07	0.46	0.07	1.15	0.13	0.19	nd	nd	0.04	2.20	0.51
GH18	rim	turquoise	transparent	18.6	1.95	7.99	1.63	0.40	1.66	0.23	1.26	0.25	0.67	0.09	0.64	0.09	1.24	0.14	0.12	nd	0.05	7.68	2.19	0.80
GH20	base	colourless	transparent	19.1	2.10	8.30	1.67	0.33	1.70	0.23	1.24	0.26	0.73	0.11	0.76	0.11	1.82	0.20	0.22	nd	0.01	0.05	3.58	0.70
GH21	base	blue	translucent	18.2	1.91	7.85	1.64	0.39	1.65	0.23	1.23	0.25	0.66	0.09	0.66	0.09	1.31	0.14	0.25	nd	0.06	3.59	2.13	0.95

(*continued on next page*)

Table 3 (*continued*)

Sample	Typology	Colour	Opacity	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Pt	Au	Bi	Th	U
GH22	bracelet	black	opaque	24.2	2.60	9.93	1.87	0.49	2.06	0.25	1.30	0.25	0.73	0.10	0.70	0.10	1.22	0.22	0.18	nd	nd	0.01	3.64	0.77
GH23	handle	**aqua** with yellow trails	transparent	26.0	2.99	11.8	2.31	0.60	2.61	0.32	1.73	0.36	1.01	0.15	1.06	0.15	2.59	0.31	0.24	nd	nd	0.07	4.95	0.99
		aqua with **yellow trails**	opaque	22.2	2.58	10.4	2.00	0.55	2.38	0.30	1.63	0.32	0.91	0.14	0.97	0.14	2.69	0.26	0.28	nd	0.01	5.11	4.34	0.88
GH24	foot	green	transparent	19.1	2.11	8.56	1.78	0.40	1.81	0.25	1.38	0.27	0.76	0.11	0.76	0.11	1.57	0.19	0.10	nd	0.01	10.3	2.71	1.08
GH25	base	colourless	transparent	14.2	1.59	6.43	1.33	0.40	1.50	0.20	1.17	0.23	0.64	0.09	0.61	0.09	0.84	0.10	0.40	nd	0.04	0.13	1.56	1.24
GH26	handle	light green	transparent	18.4	1.99	7.84	1.57	0.33	1.62	0.22	1.22	0.24	0.69	0.10	0.72	0.11	2.02	0.24	0.22	nd	0.01	0.16	3.43	0.95
GH27	handle	light green	transparent	19.2	2.08	8.32	1.61	0.34	1.58	0.21	1.25	0.25	0.72	0.11	0.75	0.11	2.13	0.26	0.31	nd	0.09	0.13	3.81	1.04
GH28	handle	light green	transparent	18.5	1.99	7.83	1.54	0.32	1.46	0.21	1.16	0.23	0.64	0.09	0.67	0.10	1.81	0.19	0.25	nd	0.01	0.09	3.07	0.78
GH29	handle	light green	transparent	16.5	1.71	6.60	1.24	0.25	1.22	0.17	0.96	0.19	0.56	0.08	0.57	0.08	1.79	0.24	0.33	nd	0.01	0.49	3.08	0.89

Particularly, it could be the tapering neck of a bottle that was reworked and turned into a small drinking vessel (Carboni, 2001). GH09 and GH20 are umbo bases with manufacturing marks (probably pontil marks). GH24 is a ring foot and there is a nucleus of unknown material visible from the cross-section. The material probably derives from the laying period. GH01 and GH17 are two body fragments with dimensions between 1.6 cm (minimum) and 3.9 cm (maximum). Both of them show the presence of decorative patterns. GH01 has a double thread of shallow brown glass, typical of beakers, bottles and pitchers. GH17 has stamped or pinched decorations with dots defining a geometrical motif; due to the presence of manufacturing marks, a pinched decoration is the most plausible hypothesis. This technique is of Sasanian heritage and it is particularly widespread in the Iranian lands during the Islamic period (11th – 12th CE). Almost all of the six handle fragments have one or two oblong bulges divided by a depressed short line. This trait is either indicative of a junction point between the handle and the vessel, or it is part of the decorative feature (see fragments GH26 and GH27). The jewellery comprises bracelets and one *faience* bead. All the bracelets are made of black glass and they all show the presence of a surface patina caused by the burial period. Only a few hypotheses can be made about the manufacturing techniques. Taking into account the thickness of the walls, some samples (GH01, GH12, GH14) could have been manufactured by free-blowing. Conversely, samples (GH09, GH21) with a thickness ranging between 0.5 cm and 0.7 cm may have been made by mould-blowing.

All samples were preliminary cleaned by demineralized water and dentist tools, softly scraping the surfaces to remove remains of soil and dirt. An Olympus S761 stereomicroscope (magnification up to 45×) associated with an Olympus Soft Imaging Solutions GMBH model SC100 camera was used for a preliminary morphological observations and documentation. Polished sections were prepared by embedding samples in a polyester resin. After polishing, sections were carbon-coated to perform Electron Probe Micro-Analysis (EPMA). EPMA analyses were carried out to determine the bulk chemistry of all samples. The chemical analyses of major and minor elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, S, Cl, Cr, Co, Cu, Sn, Sb, and Pb) were performed using a Cameca SX 50 microprobe equipped with four scanning wavelength-dispersive spectrometers (WDS). A beam current of 20 nA and an acceleration voltage of 20 kV were used. Synthetic pure oxides were used as standards for Al, Cr, Fe and Sn, synthetic $MnTiO_3$ for Mn and Ti, wollastonite for Si and Ca, albite for Na, periclase for Mg, PbS for Cl and Pb, orthoclase for K, apatite for P, sphalerite for S, Sb_2S for Sb and pure elements for Co, Cu, Ni. Smithsonian Glass A standard was also employed as a reference sample (Jarosewich, 2002). Seven points were analysed on each sample to test the homogeneity and the mean value was calculated. The detection limits for the minor elements were between 0.01 and 0.04 wt%. Corning A glass standard was analysed as unknown at regular intervals throughout the analytical run to monitor precision and accuracy (Table S1a).

Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) was carried out at the Institut de Recherche sur les Archéomatériaux Centre Ernest-Babelon (IRAMAT-CEB, CNRS, France) to determine the concentration of major, minor and trace elements. The analyses were performed on the polished cross sections using a Resonetics M50E excimer laser at 193 nm and a Thermo Fisher Scientific Element XR mass spectrometer (for detailed descriptions of the set up and analytical parameters see Gratuze, 2016). The laser was operated at an energy of 5 mJ, a pulse frequency of 10 Hz and with a beam diameter typically at 100 µm. A 20s pre-ablation time was followed by 30s signal acquisition for 58 isotopes (from Li to U). Five reference standards (NIST610, Corning B, C, D and APL1) were used for external calibration and to calculate the quantitative concentrations for all elements (Gratuze, 2016). Corning A and NIST612 were analysed as unknowns at regular intervals throughout the analytical run to monitor precision and accuracy (Table S1b).

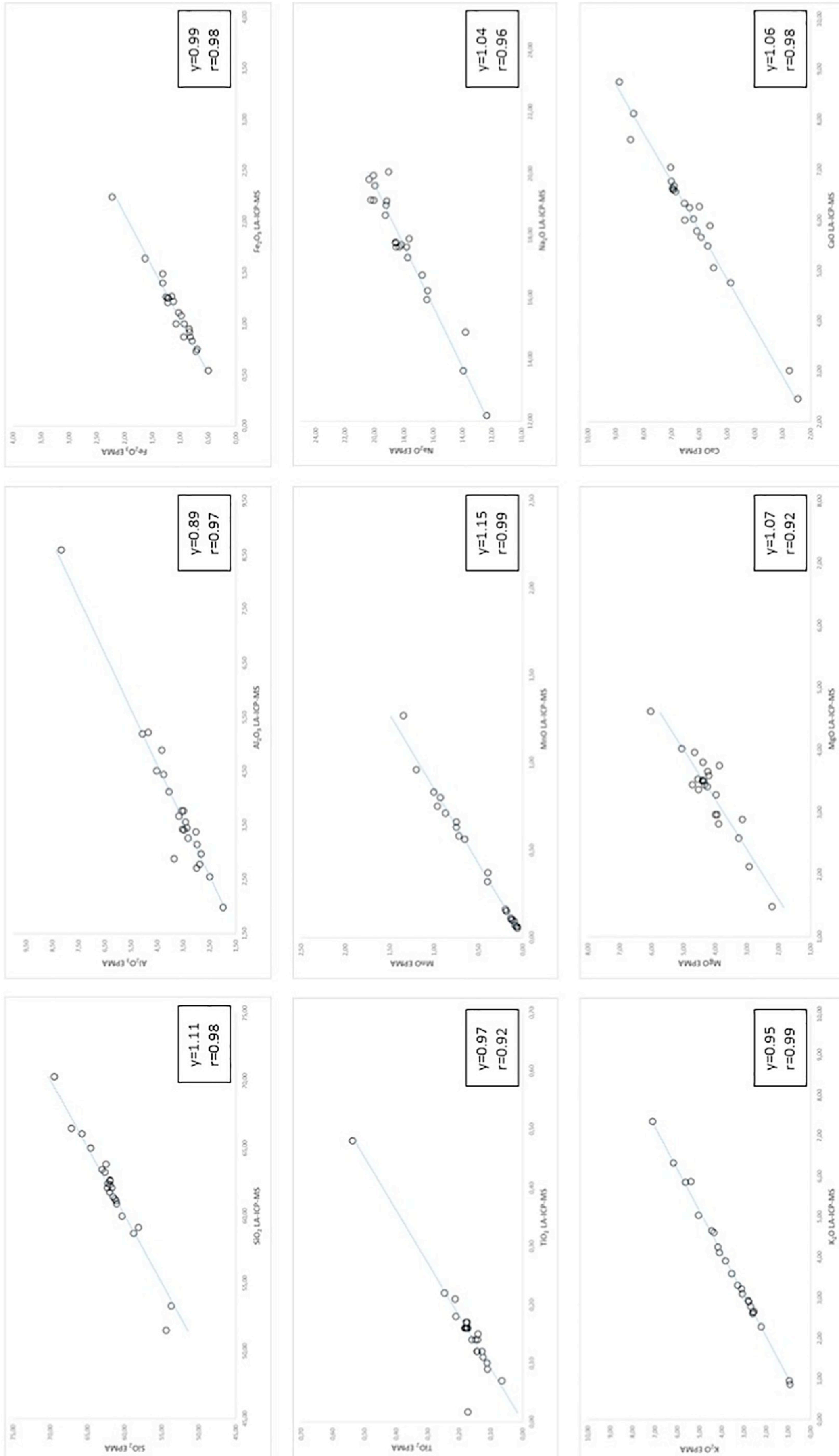


Fig. 2. Comparison between EPMA and LA-ICP-MS data.

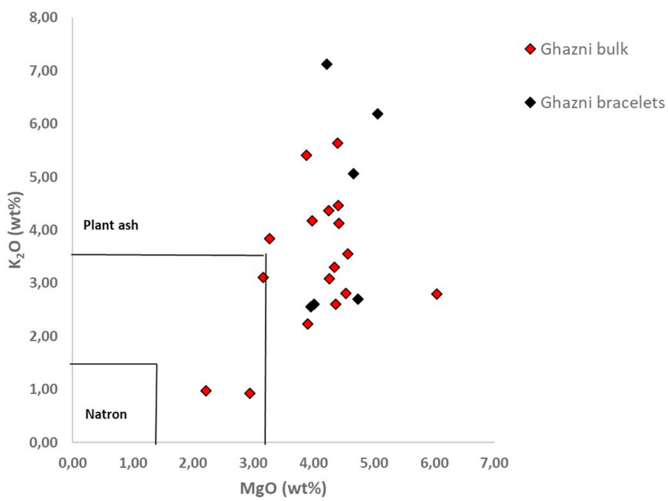


Fig. 3. K_2O versus MgO scatter plot. Distinction between natron- and plant ash-based glass in accordance with Lilyquist and Brill, 1993

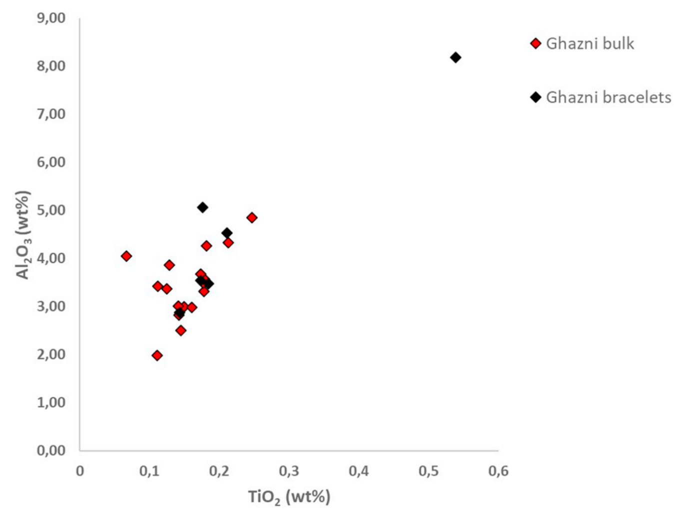


Fig. 4. Al_2O_3 versus TiO_2 scatter plot.

3. Results

The composition of the major and minor oxides, obtained by EPMA, is reported in Table 2 and LA-ICP-MS data are shown in Table 3. The two dataset compare very well across all the major and minor elements (Fig. 2). Pearson's linear correlation coefficients range between 0.96 and 0.99, indicating a strong positive correlation. In addition, the angular coefficient are very close to one, suggesting a good agreement between the two techniques (see also Ceglia et al., 2017). The only exception is MgO, with a slightly lower Pearson's coefficient (0.92) and a higher dispersion of measurements. To make the reading smoother, quantitative data for major and minor oxides obtained from EPMA analysis will be employed in the text and in the scatterplots, while for the trace elements LA-ICP-MS data will be used.

The analysed fragments from Ghazni are all of a soda-lime-silica glass type (Fig. 3). All but two samples (GH01 and GH09) have K_2O contents between 2.23 wt% and 7.12 wt% and MgO between 3.16 wt% and 6.04 wt%, consistent with the use of a vegetable soda source as fluxing agent, like halophytic plant ash. Samples GH01 and GH09 are characterised by lower K_2O (< 1 wt%) and MgO (< 3 wt%). They also show lower P_2O_5 (0.23 wt% and 0.17 wt%) and CaO (2.46 wt% and 2.76 wt%) compared to the other analysed fragments. Although K_2O, P_2O_5 and CaO contents appear to be consistent with the use of natron as a flux, MgO is excessively high compared to the values reported in the literature (Lilyquist and Brill, 1993). A closer affinity may be established with the so-called intermediate MgO-rich group, including plant-ash based, mixed-alkali and recycled glasses (Gliozzo, 2017).

In order to identify the source of silica used as vitrifying agent, aluminium and titanium oxide contents have first been considered, as these oxides reflect the feldspar and heavy mineral contents of the silica sources (i.e. Brems et al., 2012; Freestone et al., 2018). Given the elevated alumina (> 2%) and titanium (> 0.1%) levels and their positive correlation, sand was the likely source of silica rather than quartz pebbles (Fig. 4). Nd data further confirm this interpretation. The contents range from 5.90 ppm to 26.9 ppm, consistent with values reported in the literature for siliciclastic sediments and sedimentary rocks (Brems et al., 2013). Nd is furthermore correlated with Al_2O_3, indicating that Nd is related to the use of sand as network former (Degryse et al., 2010).

The trace element patterns highlight some differences between the samples. GH01, GH09 and GH25 show slightly different trace element patterns compared to the bulk assemblage (Fig. 5a). In particular, sample GH25 is characterised by higher Sr and Ba contents (probably related to the high Mn contents), with more depleted Ti, Cr, Zr and Hf. In contrast, GH01 and GH09 display lower Sr and Ba contents. Some of the bracelets (GH02, GH04 and GH22) have likewise different trace element patterns (Fig. 5b) compared to the bulk of the assemblage, while others (GH07, GH11 and GH16) approximately match it. More precisely, bracelets GH04 and GH22 have slightly lower Sr and distinctively higher Ba contents; bracelet GH02 is different from all other bracelets as it shows higher concentrations of all elements. It is likely that bracelet GH02 has been manufactured by using a different type of sand, as suggested by its higher Al_2O_3 (8.18 wt%), TiO_2 (0.54 wt%) and Fe_2O_3 (2.23 wt%) contents. In the following section, bracelets will be discussed as a separate cluster due to their peculiar compositional features.

The compositional data also show that all light green, turquoise and blue fragments have elevated MnO contents (> 0.2 wt%; Table 2), presumably indicating the intentional addition of manganese to the glass batch (Sayre, 1963; Brill, 1995; Jackson, 2005). The practice of deliberately adding MnO seems to have increased in the Islamic period, as attested by several studies dealing with assemblages from both Syria-Palestine and the Middle East (Swan et al., 2017). Colourless glass fragments (GH09, GH20 and GH25) have slightly higher MnO contents, ranging from 0.96 and 1.35 wt% and acting as a decolourant. Blue, turquoise and green samples show higher CuO contents compared to other samples, likely to be responsible for the colour shades.

4. Discussion

A Al_2O_3:MgO/CaO scatter plot shown in Fig. 6 provides a comparison between analysed glasses from Ghazni and published data of Islamic glass assemblages, although for some of the assemblages a local primary glass production has not been attested. Comparative materials are considered from both the Levant, found at sites like Ramla, Tyre, Beirut, Raqqa and Damascus (Henderson et al., 2016; Phelps, 2018), and Central Asia, unearthed at Nishapur (Henderson et al., 2016; Phelps, 2018), Sīraf, Iran (Swan et al., 2017) Ctesiphon (Henderson et al., 2016) and Samarra, Iraq (Schibille et al., 2018); Sasanian glasses from Veh Ardašīr, Iraq (Mirti et al., 2008, 2009) are also used for comparison.

This diagram 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: more

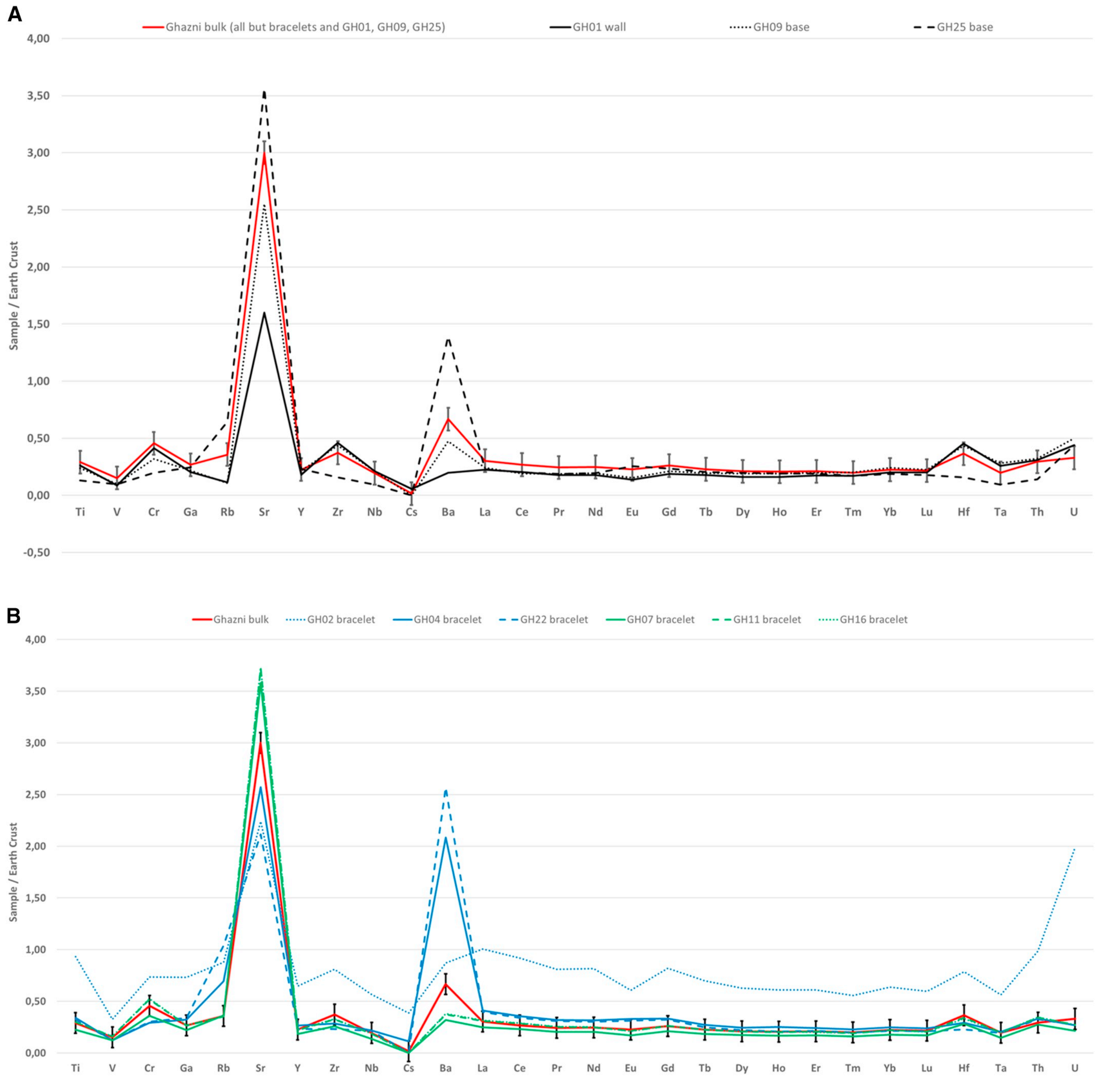


Fig. 5. Trace elements patterns obtained by LA-ICP-MS, with averages normalised to the mean values in the continental earth crust (Kamber et al., 2005); a) bulk assemblage compared to outliers and b) bulk assemblage compared to bracelets.

specifically, plant ash glasses from eastern regions tend to have higher MgO/CaO ratio and higher MgO than glasses from Syria-Palestine (Freestone, 2006; Simpson, 2014; Henderson et al., 2016; Phelps, 2018). The glasses from Ghazni plot alongside 9th-11thcentury eastern glasses from Central Asia. More precisely, they fall within the area of so-called "Mesopotamian type 1" compositional group, encompassing: "Sasanian 1" plant ash-based glasses from Veh Ardašīr, Iraq (Mirti et al., 2008, 2009); 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).

Further insights into the raw materials employed in glassmaking, with specific reference to the sands working as network former, are discernible from variation in specific trace elements. It has recently been highlighted that Cr, La, Zr and Ti can be useful to distinguish between production areas located in the Syria-Palestine region and Central Asia, since differences in these trace element concentrations could be connected to the geochemistry of sand sources. In particular, Central Asian samples tend to show significantly higher Cr for a given

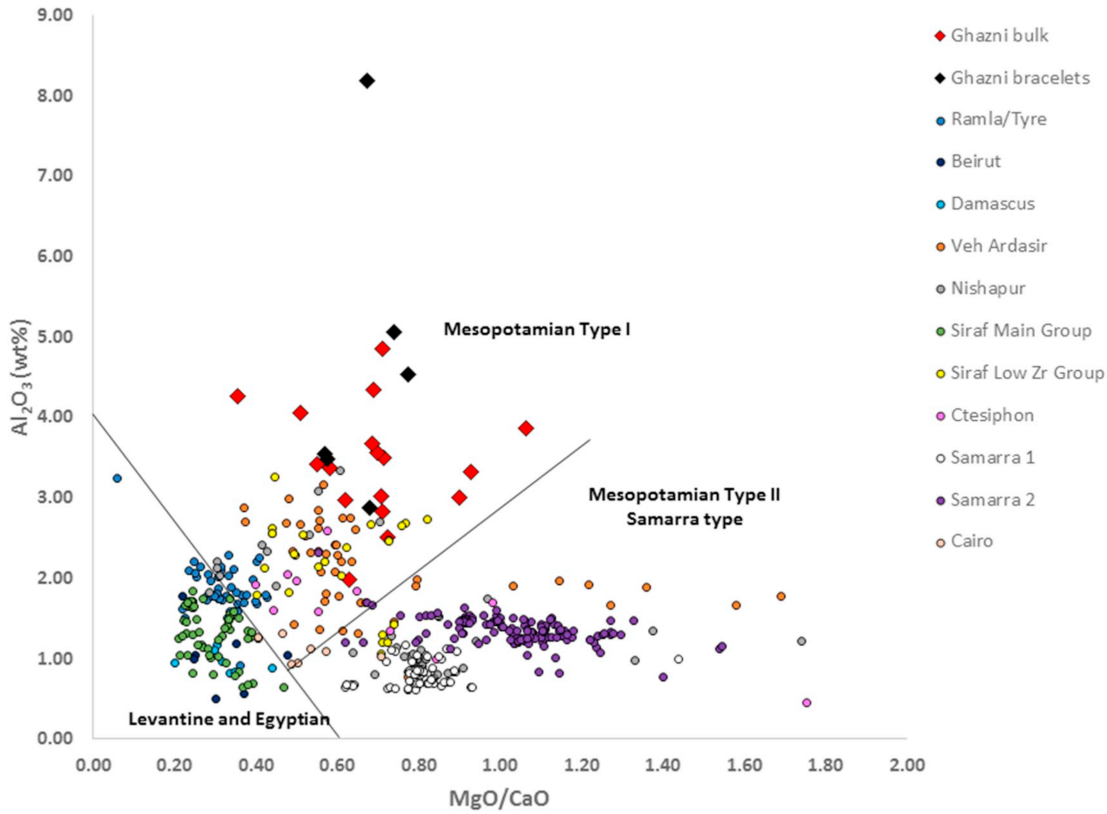


Fig. 6. Al_2O_3 versus MgO/CaO scatter plot. Comparison data from: Henderson et al., 2016; Mirti et al., 2008, 2009; Phelps, 2018; Schibille et al., 2018; Swan et al., 2017

amount of Fe compared to the Syro-Palestinian samples, as well as higher Cr/La ratios. Zr/Ti ratios tend, in contrast, to be lower in Central Asian glasses (Henderson et al., 2016; Mirti et al., 2008). In Fig. 7a Cr/La and Zr/Ti ratios for the assemblage from Ghazni are plotted and compared to published data for glasses from 9th–11th century Iran (Nishapur, Sirāf), 9th–10th century Iraq (Samarra, Ctesiphon) and Sasanian 4th–5th century Veh Ardašīr, 9th–12th century Syro-Palestine (Beirut and Damascus) and 14th–15th century Egypt (Cairo). Glasses from Ghazni form a relatively well-defined cluster that does not exactly match any of the other assemblages but that shows some similarities with so-called Group 1 from 9th-century Samarra. However, the titanium to zirconium ratios (Fig. 7b) of the Ghazni samples differ significantly from all other published data. The trace element data therefore suggest that the glass underlying the Ghazni assemblage was manufactured from sand sources with a mineralogical signature affine to 9th- to 11th-century CE glass assemblages from other central Asia sites but with local variations.

Special attention has to be payed to the set of bracelets found at Ghazni. On the one hand, bracelets GH07, GH11 and GH16, resembling the bulk composition of the assemblage from Ghazni closely, thus corresponding to the so-called "Mesopotamian I" group. On the other hand, bracelets GH02, GH04 and GH22 have different compositional features, in particular higher K_2O and Al_2O_3 contents (Fig. 8a). The closest affinities can be identified with two assemblages of high alumina glasses: a group of vessels found at Kuva and Akhsiket in the Ferghana Valley, eastern Uzbekistan (Rehren et al., 2010), and a set of bracelets from Tell Abu Sarbut and Khirbat Faris, in Jordan (Boulougne and Henderson, 2009). The 10th- to 11th-century plant ash-based glasses from the Ferghana Valley have very high alumina concentrations (in the range between about 3 wt% and 8 wt%). Although high alumina glasses are generally associated with an Indian provenance, those found in the Ferghana Valley have been ascribed to a local production, as suggested by higher MgO and K_2O contents (mean values of 3.10 and 3.48 wt%, respectively) and the discovery of the remains of a kiln with adhering glass (Rehren et al., 2010). The elevated alumina contents have been interpreted as the result of an increased contamination of the glass melt from the alumina-rich kiln material, but further research is needed to ascertain this hypothesis. In contrast, the high alumina bangles from Jordan have been interpreted as deriving from a mixture of Middle Eastern plant ash glass and imported high alumina glass, as suggested by their very high Na_2O (14.71 wt%–21.38 wt%) and K_2O (4.59 wt%–9.17 wt%) levels. It has been proposed that part of the glass originated in either Central Asia or the Far East, and that it would have reached the Levant either via the Silk Roads or by sea (Boulougne and Henderson, 2009). The high alumina bracelets from Ghazni (GH02, GH04 and GH22) have Al_2O_3, K_2O and Na_2O contents comparable to those reported for the high alumina bracelets from Jordan and high alumina glasses from the Ferghana Valley (Fig. 8b). Compared to the bulk assemblage from Ghazni, bracelets GH04 and GH22 also have higher Ba and Sr contents. This suggests that Ba is related to the carbonate fraction of a beach sand and implies the use of a different type of sand as network former (Brems and Degryse, 2014). Due to the limited number of available bracelets from the assemblage under study and the restricted comparisons from the literature, it is not possible to draw any further conclusions about the provenance of these high alumina bracelets. Contamination through secondary working is also a possibility, though it cannot currently be unambiguously ascertained.

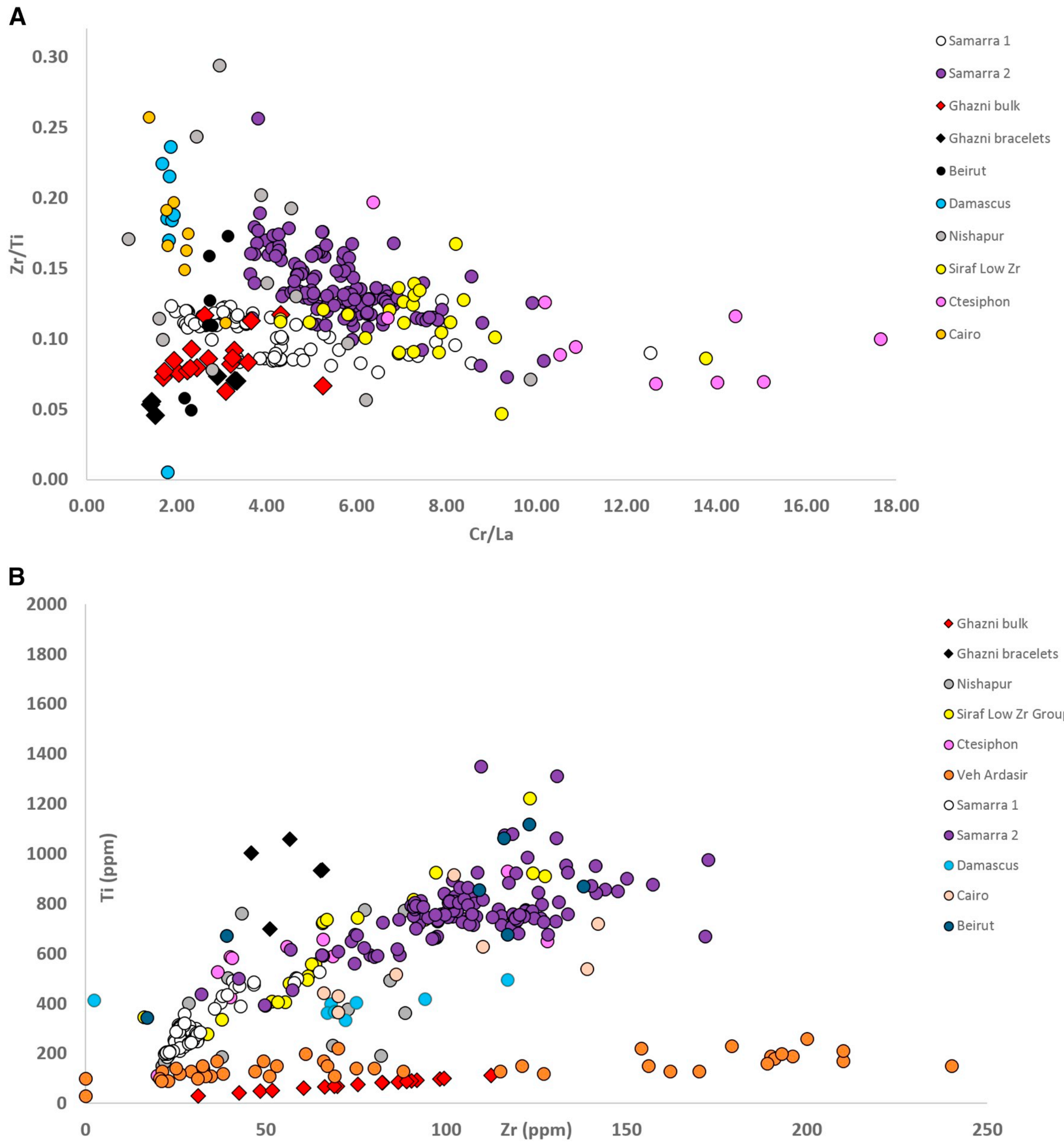


Fig. 7. a) Cr/La versus Zr/Ti and b) Zr versus Ti scatter plots. Comparison data from: Henderson et al., 2016; Mirti et al., 2008, 2009; Schibille et al., 2018; Swan et al., 2017

5. Conclusions

Some remarkable inferences can be drawn from the results achieved from analyses carried out on glass objects found at the Ghaznavid Palace in Ghazni (Afghanistan). All the analysed objects were manufactured by using a plant ash-based glass in line with Central Asian glassmaking technology. Regarding the glassware, the closest affinities have been shown with so-called "Mesopotamian I" type, a compositional category identified among 9th- to 11th-century CE plant ash-based glass assemblages from Central Asia. Trace element patterns provided further insights on the raw materials, indicating the use of sand sources that are mineralogically related to glasses from 9th- to 11th-century sites in Central Asia, while exhibiting fundamental local differences, particularly in the zirconium relative to titanium concentrations. Taken together, a Central Asian provenance of the Ghazni vessel glass appears likely. A somewhat different scenario can be outlined for the bracelets that are compositionally more variable. While half of the bracelets display the same chemical signatures as the glassware from Ghazni, others have very different compositional features more akin to some high alumina glasses found in the Ferghana Valley, Uzbekistan,and Jordan. Results seem, therefore, to indicate the existence of different trade contacts between Ghazni and various regions in Central Asia. On the one hand, the glassware seems to have been manufactured with sands having a mineralogical signature quite similar to glasses from Central Asia; on the other hand, bracelets suggest the opening of further routes, indicating, in particular, possible relations with either Uzbekistan or Jordan.

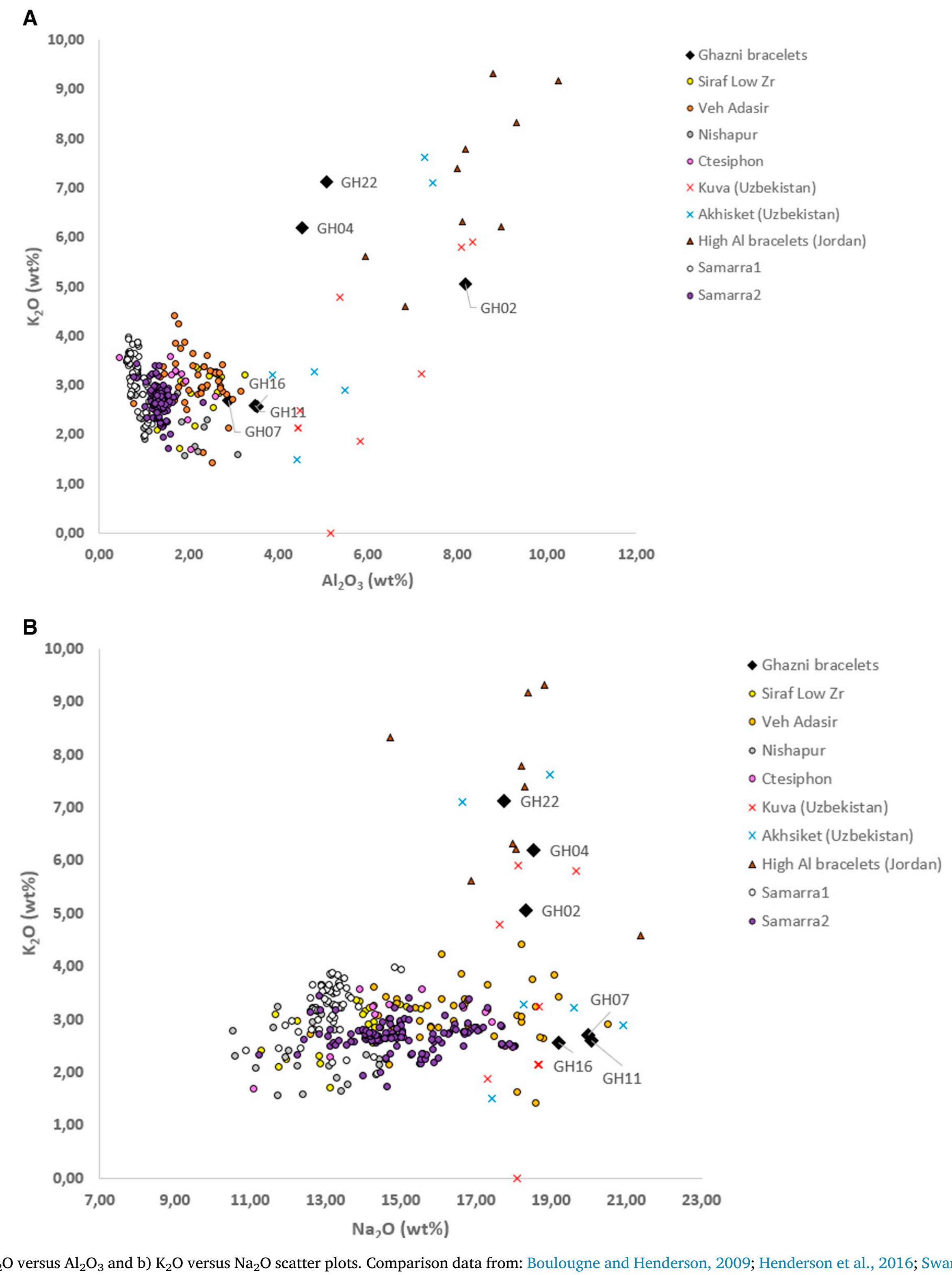


Fig. 8. a) K_2O versus Al_2O_3 and b) K_2O versus Na_2O scatter plots. Comparison data from: Boulougne and Henderson, 2009; Henderson et al., 2016; Swan et al., 2017; Rehren et al., 2010

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2019.04.002.

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